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# NAVAL POSTGRADUATE SCHOOL

## Monterey, California



# THESIS

Marine Atmospheric Boundary Layer  
and Inversion Forecast Model

by

DAVID ALMY BROWER

MARCH 1982

Thesis Advisor:

K. L. DAVIDSON

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Item 20 (cont.)

planetary boundary layer capped by an inversion. The initialization is based on radiosonde data and, as such, the code was developed to be used with the Integrated Refractive Effects Prediction System (IREPS) assessment Code. It has been extended to be used with any single platform having atmospheric sensing capabilities, radiosonde or dropsonde. IREPS and hence the MABL prediction code are under consideration for inclusion in Tactical Environmental Support System (TESS).



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Marine Atmospheric Boundary Layer and Inversion  
Forecast Model

by

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Lieutenant, United States Navy

B.S., United States Naval Academy, 1974

Submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE IN SYSTEMS TECHNOLOGY

from the

NAVAL POSTGRADUATE SCHOOL

March 1982



## ABSTRACT

A computer code for prediction of the marine atmospheric boundary layer is developed. The code is used to predict changes of the capping inversion height, the strength of the specific humidity and potential temperature 'jumps' at the inversion, the well-mixed relative humidity in the layer and the lifting condensation level for possible cloud/fog formation. The code is based on recently formulated integrated models for the clear or cloudy marine planetary boundary layer capped by an inversion. The initialization is based on radiosonde data and, as such, the code was developed to be used with the Integrated Refractive Effects Prediction System (IREPS) assessment code. It has been extended to be used with any single platform having atmospheric sensing capabilities, radiosonde or dropsonde. IREPS and hence the MABL prediction code are under consideration for inclusion in Tactical Environmental Support System (TESS).





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## I. INTRODUCTION

Modern warfare has become critically dependent on the entire electromagnetic spectrum for command and control communications, for weapons guidance, for electronic warfare support and for countermeasures. Tactically essential systems are highly affected by the environment even when conditions are not severe in the historical sense. Enhancement or degradation of the operational performances of EM/EO systems has become a primary concern of task force commanders. As such, the deployment of resources and the modification of tactics based upon environmental factors in EM/EO propagation will, to a very large extent, determine the effectiveness of sensor, weapon and communications systems.

Environmental effects on EO/EM system performance can be grouped in the general categories of refraction (EM), wave front distortion (EO), extinction (EO), and dispersion (EM/EO). Environmental factors contributing to these effects are the vertical gradients of pressure, temperature and humidity for refraction, small scale inhomogenities (turbulence) of the index of refraction for wave front distortion, concentration of water vapor and size distributions of aerosols for extinction and turbulent transport for dispersion. All of these factors are multi-variable in terms of their dependence on the routinely



measured and predicted meteorological variables: pressure, wind, temperature and moisture. The gradient of the index of refraction is the only factor for which the required accuracy exists for direct description by existing or forseen measurement capabilities. Turbulence and aerosol descriptions will have to be obtained by indirect methods due to measurement complexities which preclude measurement on operational ships.

There are requirements to describe all of these factors for the atmospheric region extending from the surface to 0.5-1.5 km above the surface, spanning the Marine Atmospheric Boundary Layer (MABL). The MABL is cooler and more moist than the overlying air and is capped by a layer (inversion), 50-100 meters thick, in which temperature increases and humidity decreases with height. Critical values of the index of refraction gradients leading to anomalous EM propagation can be present within the shallow capping inversion because of the humidity and temperature gradients. The entire affected region (duct) extends below the inversion, and determining its lower boundary is essential. High turbulence can be present in the inversion as well as in the surface layer and this can cause degradation of slant path optical propagation. Turbulence intensities in the inversion are usually one to two orders of magnitude greater than they are immediately below, and are two to three orders of magnitude smaller immediately above





the inversion. Tactically significant degradation of infrared energy is due to water vapor absorption and to scattering by marine aerosols, and is thus usually restricted to moist MABL.

All of the above features depend critically on local detailed vertical structure of the atmosphere. Therefore regional climatologies are not useful for operational predictions, because the significant vertical structures are lost in averaging, and also because most historical measurements do not relate to specific EM/EO requirements. Furthermore, the gradients, and hence, the affected regions cannot be explained on the basis of large scale atmospheric flows since the nature of the gradients are due to dynamic processes which are controlled by near surface as well as by larger scale features.

We believe a 'gap' has existed in past efforts to characterize the tactical environmental conditions. The gap is between two extreme approaches of relating conditions to 1) near surface observations, and 2) to larger scale predicted synoptic patterns. Clearly, to assess the above features, local measurements are desirable. Measurements (radiosondes) are made infrequently and, as time progresses, the initial point measurement becomes less applicable and a predictive scheme is needed. One must consider a transition to climatology, large scale numerical analyses and predictions, or dynamic models based on the initial



soundings which are available at the operational location. Climatology has already been addressed and discounted. Ruggles (1975) has examined the capabilities of large scale numerical procedures at remote facilities and has argued convincingly that they are not sufficient.

Needed are characterizations of coupled local oceanic and atmospheric mixed layer features for time scales from 12 to 18 hours and for spatial scales from 50 to 300 km. Significant changes occur in both mixed layers over these temporal and spatial scales. Predicting these changes is now possible using available measurements and reasonable physical models which have recently been formulated.

This paper will describe results from observational and model evaluation/formulation efforts with these models which provide evidence that tactically relevant forecasts can be made over the required scales. The MABL is emphasized in this discussion but, as will be seen, the MABL model must eventually be coupled with an Ocean Boundary Layer (OBL) model to adequately describe the system. This is the object of separate investigation by the author and faculty at NPS.

The long term objective of work in these areas is to make reliable 6-18 hour forecasts of properties within the MABL and OBL. The near term objectives are 1) to verify and reformulate existing models for the responsible physical processes and 2) to develop measurement procedures which are suitable for routine observations from a single ship or



aircraft. For the finalized model it will be necessary to predict such properties as the height of the inversion, the strength of the gradients and fluxes at the inversion and at the surface, and the values of well mixed parameters in the region between the surface and the inversion.



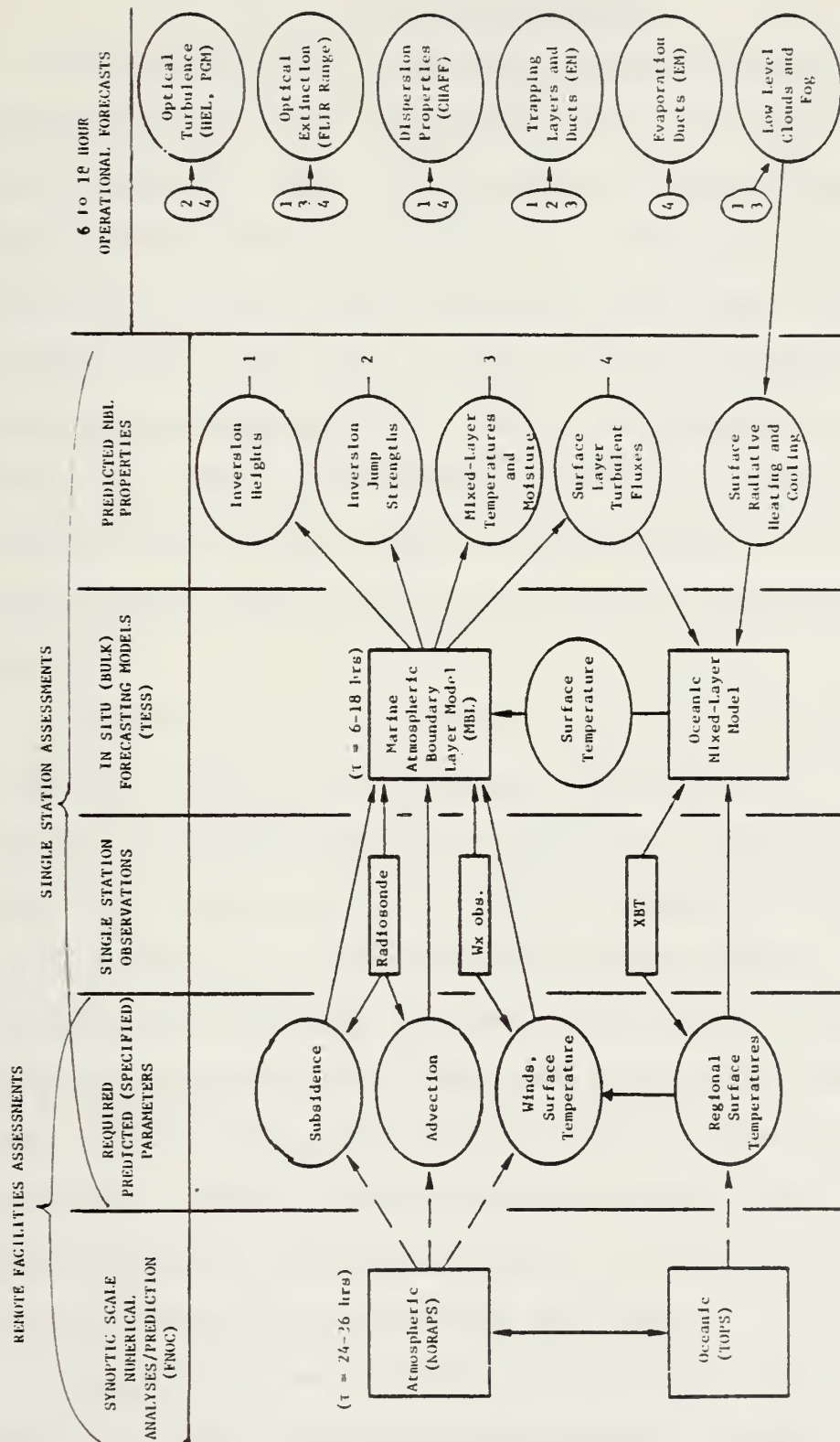


Fig. 1.

Illustration of input parameters, predicted properties and operational forecasts associated with a bulk atmospheric boundary-layer model (MABL). Numbers to the left of operational forecast items pertain to the required predicted MABL properties. The bulk atmosphere and ocean mixed-layer models would be coupled in a snipboard, aircraft micro-computer. Dashed lines (- -) coming from remote facilities imply that the required information could be obtained from these, but the in situ capabilities should be possible without the sources.





## II. BACKGROUND

This section will provide a general outline of the environmental descriptions required and the models which can be used to predict them. The possible input parameters and models are delineated in Figure 1. Tactical forecasts to which the improved understandings would apply appear on the extreme right hand side. Single station assessment constraints associated with the local atmospheric and ocean models are timely and compatible with the concept of the Tactical Environment Support System (TESS) as recently described by NEPRF scientific personnel (NEPRF METRO Report, July 1981).

As stated, we will consider only the local atmospheric mixed layer model and associated descriptions. The local oceanic predictions would be made by an oceanic mixed-layer model (e.g. Garwood, 1977) and the regional predictions would be made by a three dimensional atmospheric (e.g. NORAPS) and a regional oceanic (e.g. Tactical Ocean Prediction System-TOPS) numerical prediction model. The ocean mixed layer model and the regional numerical prediction schemes are objectives of other basic and exploratory Navy sponsored research efforts.

### A. METEOROLOGICAL DESCRIPTIONS AND MODELS

From a local perspective, let us consider an idealization of the oceanic-atmospheric system. The sea-air



interface is bordered by oceanic and atmospheric turbulent mixed layers which effectively insulate the bulk ocean and atmospheric regions. The primary sources of the turbulence within the layers are the velocity (current) and buoyancy (density) gradients at the interface. Even under conditions where the water is slightly cooler than the air, buoyancy forced velocity fluctuations within the layer can be quite large and mix the entire MABL from the surface to the inversion. The large vertical mixing yields constant (well-mixed) wind, temperature and humidity profiles above the surface. At the top of the atmospheric mixed layer there is the inversion, a thin transition region. Examples of observed well-mixed profiles and the inversion are shown in Figure 2(a).

The atmospheric mixed layer interacts with the free atmosphere at this interface by means of turbulence forced entrainment. Entrainment brings dry, warm air into the mixed layer and also increases the surface winds if there are higher winds aloft. Stratus clouds form within the layer if entrainment causes the moist mixed layer to extend above the lifting condensation level.



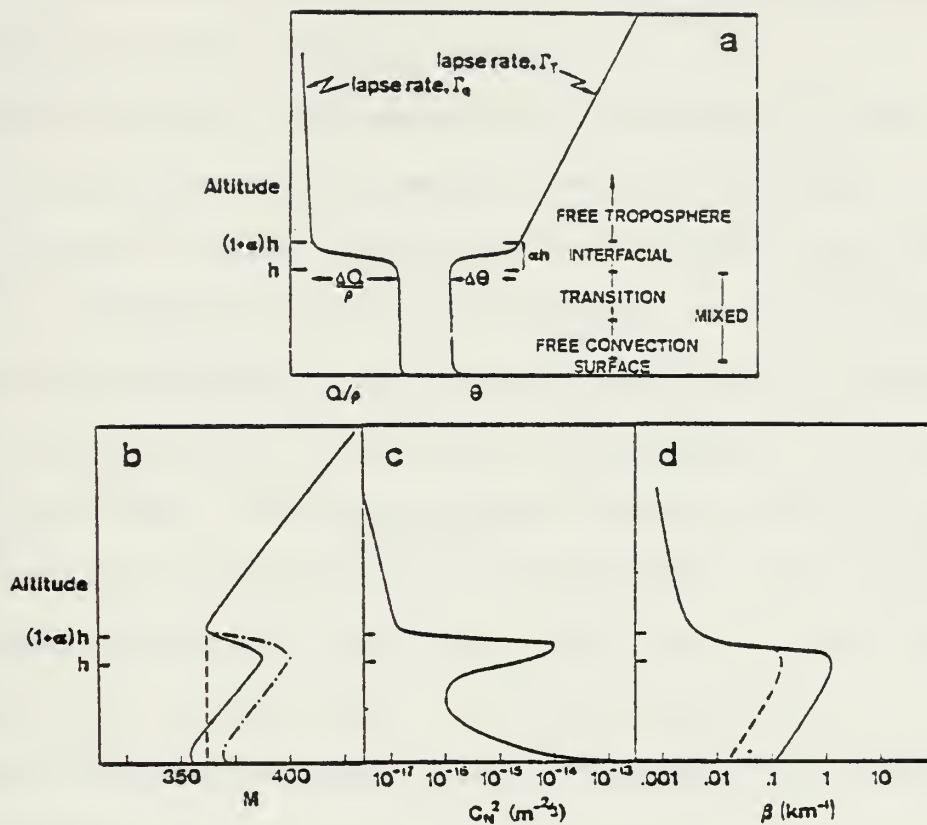


Fig. 2. Simplified meteorological and tactical features of the MABL and overlying region including (a) humidity mixing ratio,  $Q/p$ , and potential temperature,  $\theta$ , profiles and subregions, (b) modified index of refraction,  $M$ , profiles, (c) optical turbulence intensity,  $C_N^2$ , profiles, (d) total extinction coefficient,  $\beta$  (absorption and scattering), profile.



Over a time scale of 24-36 hours, physical processes within the mixed layer are also controlled by the large scale, non-stationary, synoptic flows. Synoptic scale mean vertical motion and advection will have to be prescribed or predicted over the forecast period.

The previously inferred well-mixed nature of the convective MABL has implications for the vertical distributions of mean values and the vertical flux scales of wind- $U^*$ , temperature- $T^*$  and humidity- $Q^*$ . One implication already illustrated is that properties which are conserved during mixing can be treated as being constant with height within the MABL. These parameters are the specific humidity and potential temperature for a clear MABL and equivalent potential temperature and total (vapor plus liquid) specific humidity for a cloudy MABL. A second implication is that vertical fluxes of the well-mixed parameters vary linearly with height.

These implications enable predictions of MABL evolution to be based solely on fluxes at the upper (inversion) and lower (surface) boundaries and the large scale subsidence and advection. They form the basis of recent model formulations by Deardorff (1976) and Stage and Businger (1981). Fluxes at both boundaries are due to buoyant and mechanically generated turbulence for the clear case. The linear height variations of the fluxes allows buoyant fluxes at the inversion to be more readily estimated on the basis





of general cloud features. Methods exist for estimating synoptic scale forcing from single station measurements but further efforts are required to achieve the accuracies required in MABL predictions.

In general, existing models are quite good for the clear sky MABL and fair to good for the cloudy MABL. Considerable effort is now being directed to improving the models for the cloudy MABL. The existence of cloud layers in the MABL is very sensitive to both the sea surface temperature and the entrainment rate and, in turn, clouds have a profound effect on the short and long wave radiation budget at the surface. Fairall et al (1981) provide a discussion on the approach and the status of abilities to predict the evolution of the MABL.

## B. TACTICAL DESCRIPTIONS

Figures 2b-d illustrate tactical descriptions discussed in the Introduction (appearing in the right hand column of Figure 1). Meteorological processes and features relevant to these tactical descriptions are those that were discussed above (Figure 2a and column 4 of Figure 1). Several meteorological factors affect each tactical description as indicated by the numbers, 1-4, in Figure 1. A few of the significant properties and values in the tactical descriptions are described in the following paragraphs.



The M profile in Figure 2b describes the refracted EM ray radius of curvature, relative to the earth's radius of curvature. If M decreases with height, a trapping layer is formed because the EM ray will bend downward relative to the earth. This causes the formation of a duct. The upper boundary of the duct is at the M minimum; the lower boundary is at the height where this same value of M occurs below the trapping layer, as shown in Figure 2b. The M profile is determined by pressure, temperature and humidity profiles, so values of well mixed temperature and humidity determine the lower boundary of the duct. A decrease of mixed layer M value with time could cause a surface based duct to become an elevated duct as shown in Figure 2b. This could occur if the mixed layer became warmer and drier due to entrainment of overlying air. Warming and drying of the mixed layer by entrainment would also increase the height of the evaporation duct, a ducting layer immediately adjacent to the surface. Examples of extended ranges and holes occurring with a duct appear in Figure 3 (Hitney, 1979).

The Cn2 profile in Figure 2c shows the vertical variation of turbulence which would affect optical wave front distortion. We see that Cn2 is largest near the surface and in the inversion. Values in these regions are 1-2 orders of magnitude larger than those in the mixed layer and above the inversion. Cn2 values near  $10(-14) \text{ m}^{-2/3}$  are representative for these two regions. The importance of



this value is illustrated in Figure 4 with a simulated image of a remotely piloted vehicle as viewed through Cn2 regions of 0 (no turbulence),  $10(-15)$ , and  $10(-14) \text{ m}^{-2/3}$  (Kearns and Walter, 1978).

The extinction coefficient, B, profile is shown in Figure 2d. B is inversely proportional to the range of IR systems and primarily depends on the absolute humidity and the aerosol size distribution. Aerosol size distributions depend on the generation rate of sea salt particles and on the relative humidity as determined by both the moisture and temperature. Therefore, IR extinction is very dependent on the entrainment of relatively clean, dry and warm air from above the inversion and on the surface wind generation of the sea salt particles (Davidson et al, 1982). As illustrated, the extinction coefficient is large within the mixed layer and increases with relative humidity which increases with height. The increase of extinction with height is important in slant path range considerations.



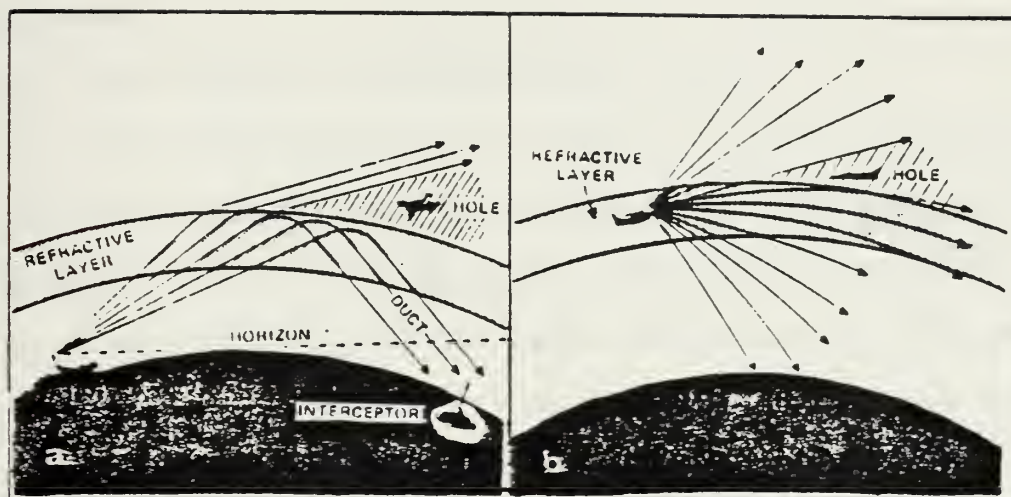


Fig. 3. Examples of extended ranges and holes for EM ducts for (a) surface-based duct and a shipboard air-search radar and (b) elevated duct and an airborne early-warning radar (from Whitney, 1979).



Fig. 4. Computer simulated image remotely piloted vehicle (RPV) as viewed with 8-12  $\mu\text{m}$  IR sensor (range 2 km, visibility 15 km, threshold 4.5 nW) through atmosphere with  $C_N^2$  values of (a) 0 (no turbulence), (b)  $3.7 \times 10^{-15} \text{ m}^{-2/3}$  and (c)  $1.0 \times 10^{-14} \text{ m}^{-2/3}$  (from Kearns and Walter, 1978).





### III. MABL OBSERVATIONS AND PREDICTIONS

A recently obtained data set will be used to demonstrate the prediction of changes in the MABL. The demonstration will show:

- a) the status of available data sets,
- b) that the assessment of relative roles of dynamic processes in the MABL can be based on a relatively simple physical model which includes specifiable inputs,
- c) that, at the present time, we only have limited evidence that changes can be predicted. The rigorous specification or description will require further interpretive efforts and, perhaps, improved formulation of the separate models.

#### A. MABL OBSERVATIONS

The data were obtained during the Cooperative Experiment on West Coast Oceanography and Meteorology (CEWCOM-78) conducted west of San Nicolas Island, CA during May of 1978. Observations of the oceanic and atmospheric mixed layers were made from the R/V ACANIA; radiosonde observations were also made at surrounding shore stations. The data to be shown are from a 48-hour period, 5/19/1200 to 5/21/1200 PST. The R/V ACANIA was cruising slowly (2-3 knots) into the wind and returned to an initial point approximately every 12 hours. The general location of the R/V ACANIA during the 5/19 to 5/22 periods and locations of surrounding shoreline



radiosonde sites appear in Figure 5.

The period was one of steady onshore flow caused by the combined effects of intensification of the Eastern Pacific High and the persistence of the Mexican thermal low. The only apparent change in synoptic scale forcing was an increase in the offshore pressure gradient. Advection in the atmosphere was moderate. However, MABL evolutions were primarily determined by subsidence, surface fluxes, and entrainment at the inversion. Satellite imagery showed uniformly increasing stratus coverage (thin to heavy) during the period with a cellular (broken) coverage occurring late on the 21st.

Acoustic sounder returns, mean surface layer parameters, and sea surface temperature during the 19-21 May period were all measured from the R/V ACANIA and are shown in Figures 6b-d. Composite potential temperature profiles from shipboard and shore station radiosonde and temperature profiles from ship deployed XBT's appear in Figures 6a and 6e, respectively. Although these descriptions of MABL and OBL changes were obtained from an instrumented research vessel, all can be obtained from operational ships. This includes the acoustic sounder record.



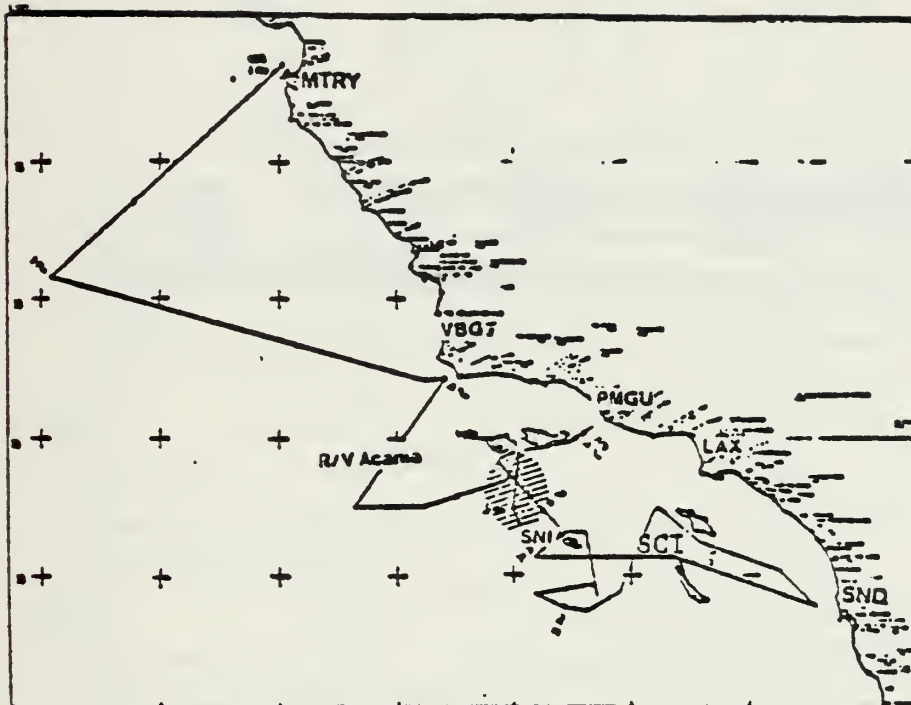


Fig. 5

Tract of R/V Acania and location of shoreline radiosonde sites during CEWCQM-78. General location of R/V Acania during 19-21 May period is indicated by hatched area N-NW of San Nicolas Island (SNI).



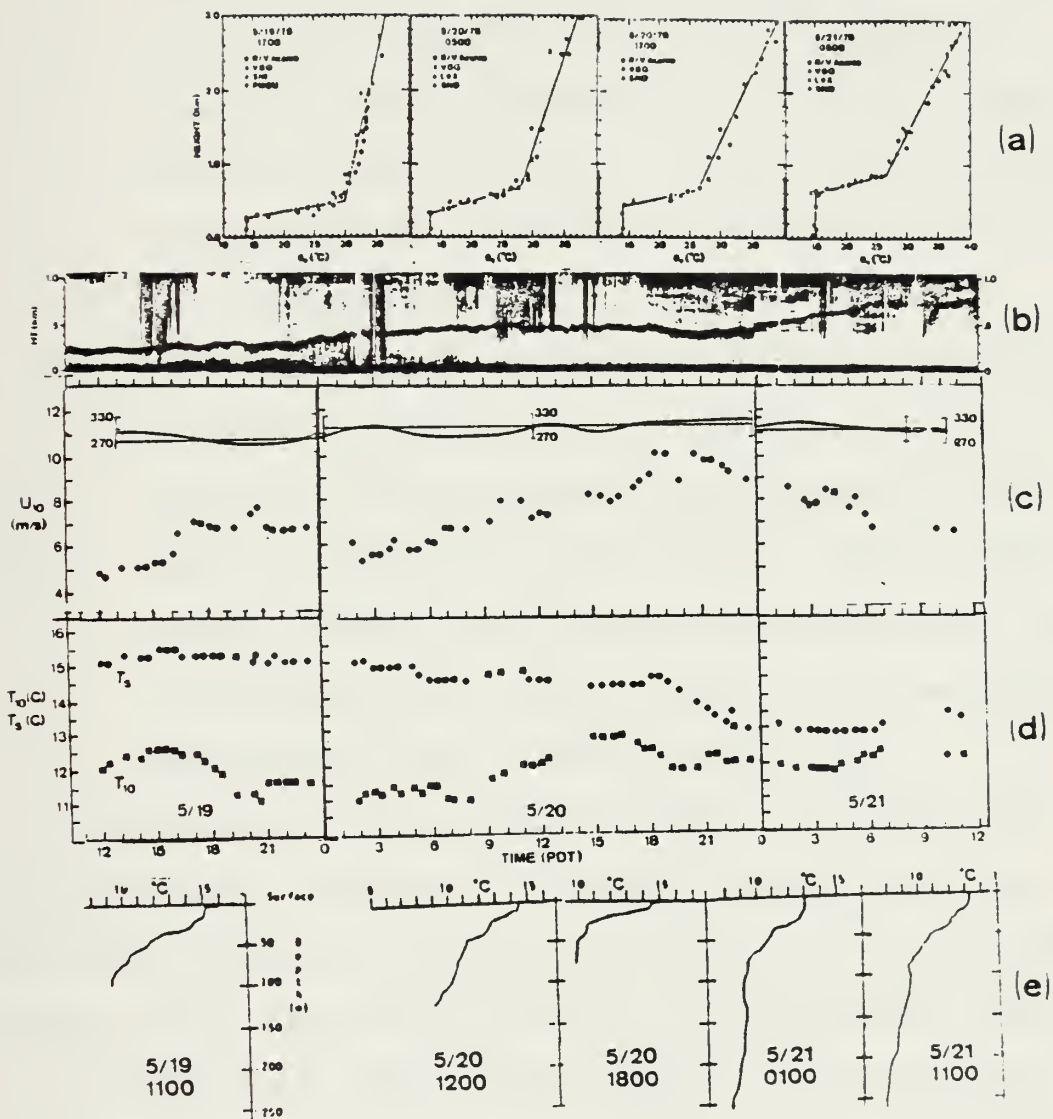


Fig. 6

Atmospheric and oceanic mixed-layer observations, during JEWCOM-78  
 (a) potential temperature composite profiles, (b) acoustic sounder  
 record, (c) 10 meter wind speed, (d) 10 meter and surface temperature  
 and (e) XBT traces. All data except indicated profiles in (a) were  
 obtained from R/V Acania.





Changes of atmospheric features which would have been tactically significant in view of the time scale and their magnitudes were:

- a) The MABL depth increased from 250 m to 750 m over the 48 hour period. The changes occurred over relatively short intervals, from 20/00 to 20/04, and from 21/00 to 21/08. The MABL depth remained nearly constant during the intervening 12 to 18 hour periods.
- b) The surface layer temperature increase from 20/00 to 20/15 is indicative of entrainment of overlying warm air. The entrainment was presumably also a factor in the wind speed increase over the same period, which caused the warm shallow ocean layer to be deepened by mixing, lowering the sea surface temperature after 20/1800 (Figure 6d).

In conjunction with changes in MABL structures and parameter values depicted in Figure 6, changes occurred which are important to operational systems. Some of these changes can be determined directly from parameters measured in this scientific observational effort. M profile and cloud base heights and condensation levels can be calculated from the measured composite humidity and temperature profiles. Surface layer extinction coefficients have to be determined from the measured humidity and aerosol size distributions. The method for determining extinction



coefficients from aerosol data has been described by Schacher et al (1981). Surface layer  $C_n2$  values and evaporation duct height can be determined with considerable certainty from measured surface layer wind, temperature, humidity and surface temperature values using expressions described by Davidson et al (1981) and Fairall et al (1978). Extinction and  $C_n2$  profiles have to be based on more recent and, hence, less substantiated expressions such as those by Wells et al (1977) and Wyngaard and Lemone (1980).

Results from these determinations appear in Figures 7 and 8 along with the composite potential temperature,  $\theta$ , and water vapor mixing ratio,  $q$ , profiles (Figure 7a) and the inversion height (Figure 8a). The observed results indicate that for the observation period:

- a) The EM duct associated with the inversion gradients evolved from being surface based to being elevated (Figure 7b) and the evaporation duct height ranged from below 5 m to above 8 m (Figure 8b),
- b) Optical turbulence,  $C_n2$ , in the surface layer varied from  $10(-15)$  to  $10(-14)$   $m^{-2/3}$  over the period (Figure 8c) and values in the inversion increased from  $10(-16)$  to  $10(-15)$   $m^{-2/3}$  (Figure 8c),
- c) Surface layer aerosol extinction in the 8-12  $\mu m$  IR region increased during the first 6 hours (5/19 1200-1800) because the relative humidity increased.



It decreased during the last 18 hours (5/20/1800 to 5/21/1200) because of relative humidity and wind decreases (Figure 8d) ,

- d) Stratus clouds persisted through the period. The base lifted from about 100 m at 5/19/1800 to 600 m at 5/21/1200. This is evident in the extinction profile (Figure 7d).



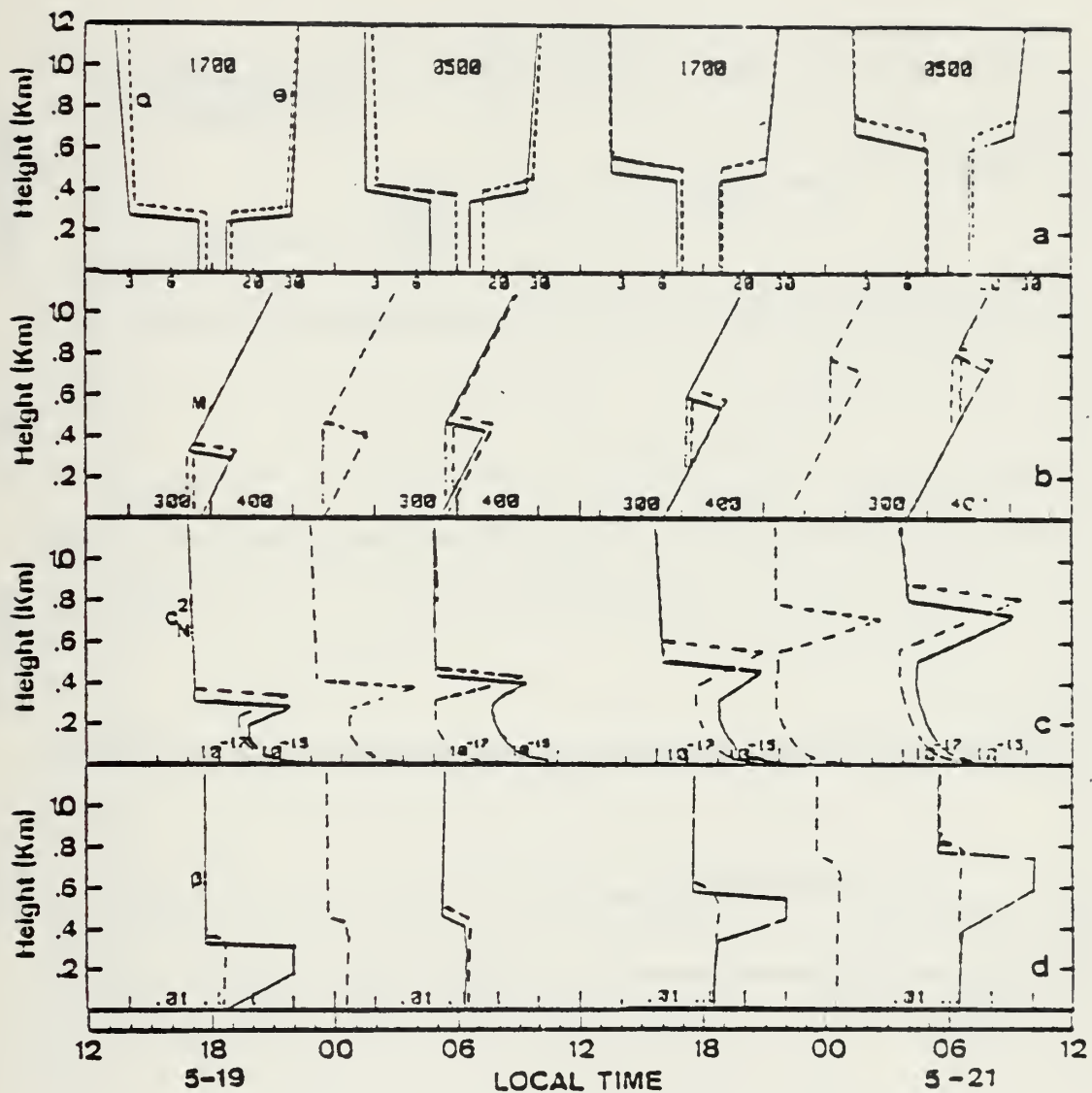


Fig. 7

Observed/computed and predicted WABL profiles for 5/19/1200 to 5/21/1200 CEWCOM-78 period including (a)  $Q$  ( $g\ m^{-3}$ ) and  $t(^{\circ}C)$ , (b)  $M$ , (c)  $C_N^2$  ( $m^{-2/3}$ ) and (d) total extinction coefficient,  $\alpha$  ( $km^{-1}$ ). Solid lines correspond to observed and dashed to model prediction.





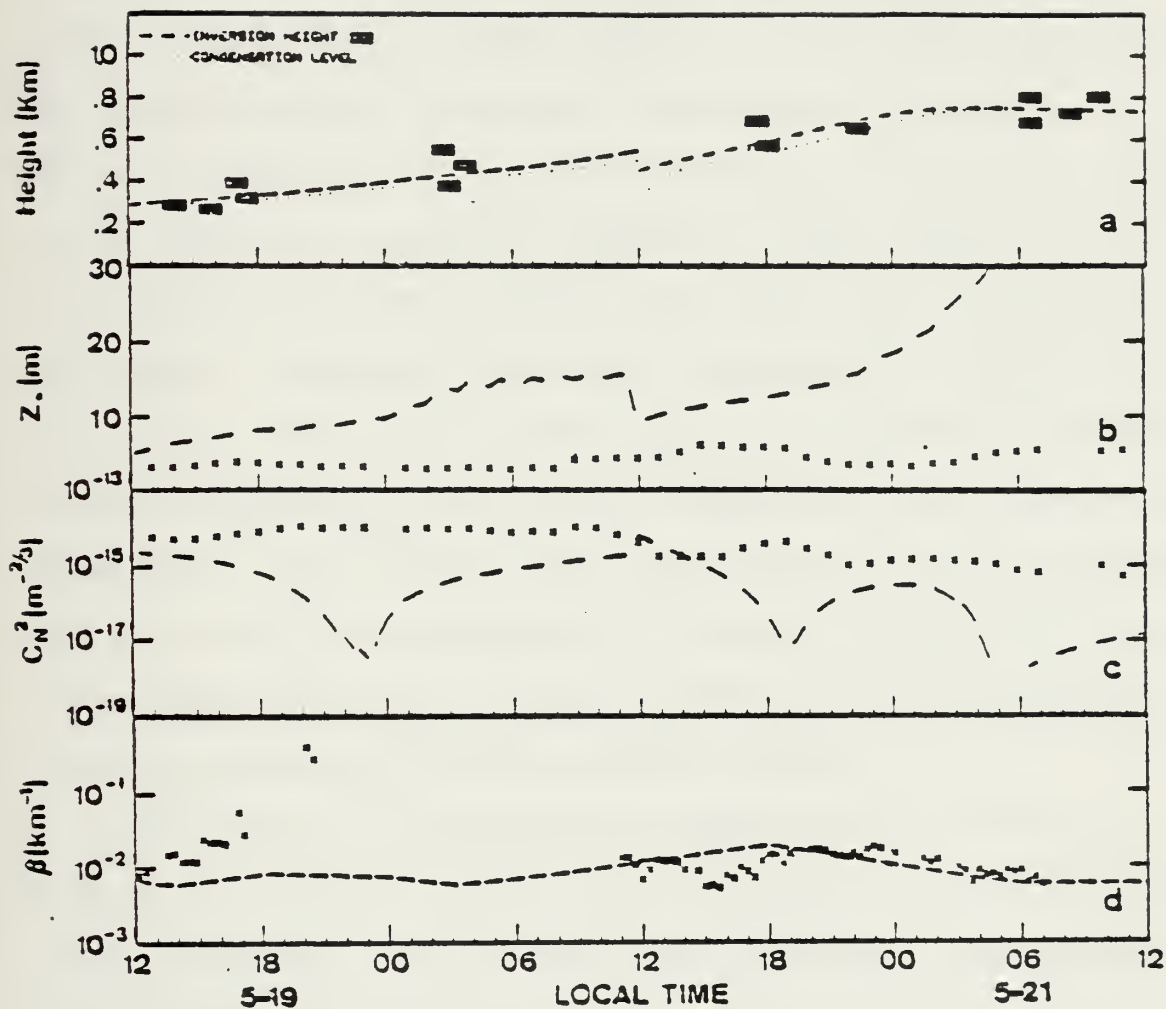


Fig. 8

Observed/computed and predicted surface layer values for 5/19/1200 to 5/21/1200 CEWCOM-78 period including (a) inversion height and lifting condensation level, (b) evaporation duct, (c)  $C_N^2$  m<sup>-2/3</sup> and (d) aerosol scattering extinction coefficient,  $\beta$ . X's are observed and dashed lines are model predictions.



## B. MODEL PREDICTIONS

During the past five years, investigations were performed on surface layer and mixed-layer scaling of small scale turbulence and aerosol properties (Davidson et al, 1978; Fairall et al, 1980; Schacher et al, 1981a and 1981b). The investigations led to the application of a time dependent MABL models based on entrainment energetics and on cloud radiative transfers suggested by both Deardorff (1976) and Stage and Businger (1981). The model requires as input an initial atmospheric sounding (radiosonde), the mean winds at a level within the surface layer (10-30 meters) and the surface temperature. Well-mixed temperature and humidity are predicted so the surface wind and wind shear at an inversion are the only local atmospheric variables which have to be prescribed. The larger scale subsidence and advection must also be prescribed for the forecast period.

The steps in the prediction computation are shown in Figure 9, where it is noted that procedures are the same for clear and cloudy cases except for entrainment computation and estimating cloud top cooling. Fairall et al (1981) include comprehensive discussions of how applicable physical processes are treated in the model and how available data can be used to estimate the processes. Because of the simplified physical model, the computations do not require numerical integration on a vertical grid so the computer storage requirements can be satisfied by available shipboard



microcomputers. In fact, the use of a hand-held calculator is being considered for these procedures. Particular computations of interest are those for the evaporation duct, the surface flux, flux of total heat and momentum and the depth change of the mixed layer. Routines for computing and graphing the M-profile can be system are used on the HP-41C/V and printer hand-held system.

Predictions of MABL changes were made with the simplified model for the 48 hour period (5/19/1200 to 5/21/1200) corresponding to observed results in Figure 6a-e. The predictions were made for two separate 24 hour periods starting at 19/1200 and at 20/1200. The initial profile for the 19/1200 starting time was that obtained at San Clemente Island (SCI in Figure 5) at approximately 1000. Initial profiles for the 20/1200 starting time were averages of the composites at 20/0500 and 20/1700. The sea surface temperatures were those at each start time as shown in Figure 6d and were 15 and 14.5 C, respectively. The surface wind observed during the forecast period was specified to increase linearly from 5 m/sec at 19/1200 to 10 m/sec at 20/2100 and then to decrease linearly to 7 m/sec at 21/1200.

Larger scale synoptic advection, was estimated to be zero from the thermal wind. Subsidence for the second period, starting at 20/1200, was adjusted on the basis of that value required for agreement between predicted and observed mixed layer depths during the first period. Hence,



the model was also used to estimate the "most probable" synoptic scale subsidence. The tuning of the subsidence value, based on comparisons of the latest sounding and predictions from a previous sounding, has been described as "hindcasting".





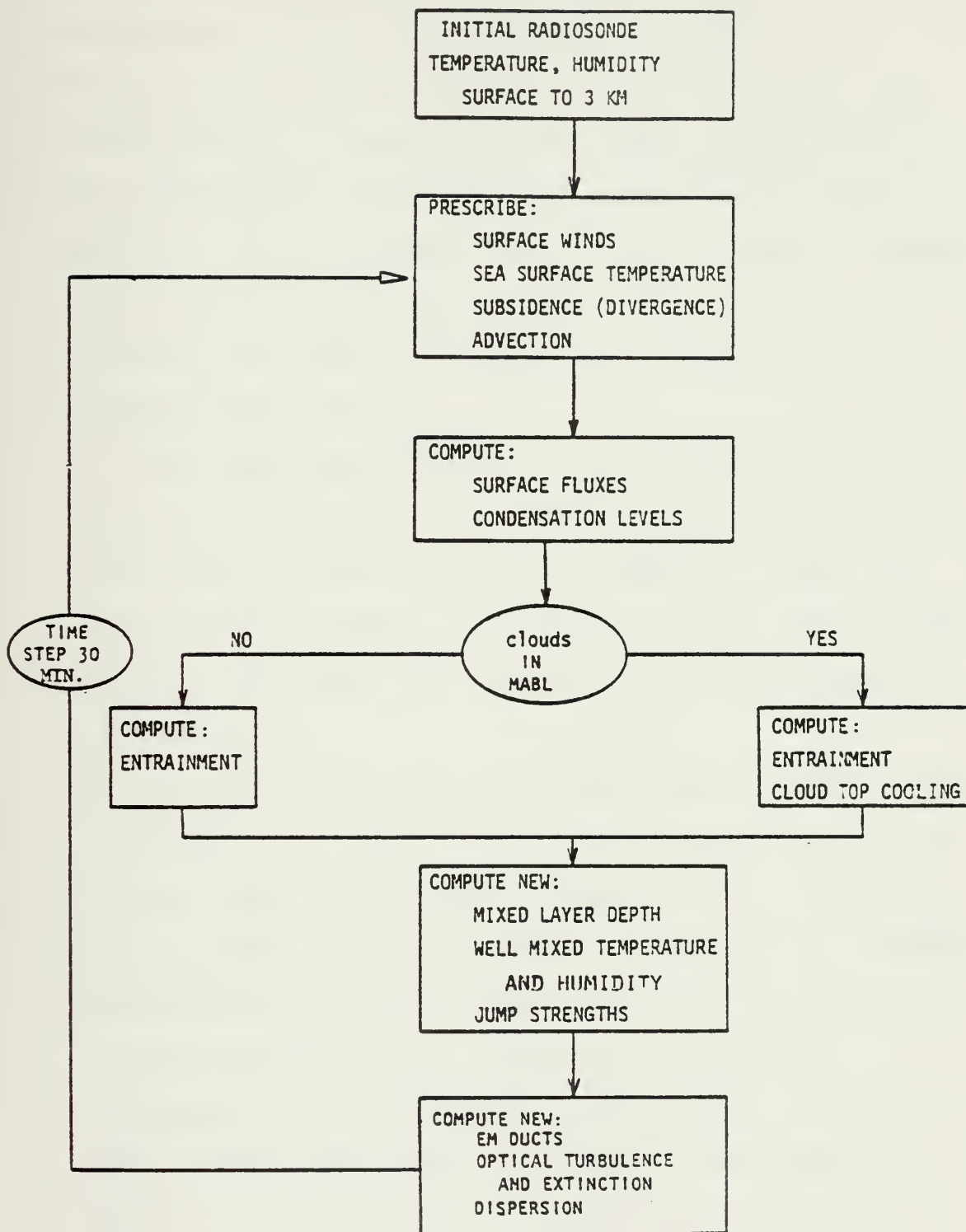


Fig. 9. SCHEMATIC OF INPUT, PRESCRIPTION AND COMPUTING STEPS IN MABL PREDICTION



The predictions are illustrated in Figures 7 and 8 along with the observed values. These predictions were made using the Deardorff (1976) cloud topped entrainment parameterization and Davidson et al (1978) surface layer parameterization. Results for the same period using the Stage and Businger entrainment parameterization appear in Appendix B. The agreement near 20/1200 in Figure 8 occurs because the model was reinitialized at that point. Significant outcomes from comparisons of observed and predicted results are:

- a) The mixed layer depth (inversion height, Figure 8a) was predicted quite well. This increase during the later part of both periods was caused by cloud top entrainment because the predicted surface layer became stable and, hence, there existed no surface buoyancy flux forcing.
- b) The cloud cover was accurately predicted to persist throughout the first period and for the first 15 hours of the second period, as indicated by the condensation level being below the inversion in Figure 8a. However, the predicted cloud thickness was less than that which actually occurred. As indicated in preceding discussions, the cloud cover was observed to break up on the 21st and the prediction after 21/0600 agrees with that.



c) The well mixed temperature and humidity and the jump predictions (Figure 7a) are reasonable except at 20/0500. The predicted well mixed temperature was too warm by 1-2 C at all other comparison times. This led to the surface layer becoming stable when in actuality it remained unstable throughout both periods (i.e. surface temperature higher than 10 m temperature.) It is believe that the cooling associated with the clouds was not sufficient. It will be seen that the surface layer was too warm and stable during the night hours.

d) The predicted M profiles (Figure 7b) were very accurate in terms of the surface based duct evolving to an elevated duct. It is interesting that even when the predicted well mixed temperature and humidity were much too high (20/0500) the M profile was verified. This occurred because their respective affects on M were compensated.

e) The predicted Cn2 profiles (Figure 7c) gave good values for the inversion region and reasonable values for the mixed layer, except for 20/0500. Agreement within a factor of three is considered reasonable for Cn2. The inversion region values were based on the convective mixing velocity,  $W^*$  (Wynngaard and Lemone, 1980) for unstable conditions. The friction velocity,  $U^*$ , was used instead of  $W^*$ , when a stable surface layer



existed (20/0500). Values above the inversion were set to 10(-13) for both observed and predicted profiles.

f) The total predicted extinction at 8-12  $\mu\text{m}$  (Figure 7d) was quite good outside of cloud layers. Again, values above the inversion were set to the same value for both observed and predicted profiles. The sensitivity of aerosol size to relative humidity becomes larger when the relative humidity is above 90%. Hence we expect this comparison to be poor in the cloud region where the relative humidity approaches 100%. However, the good agreement outside of clouds is encouraging.

g) The evaporation duct height ( $Z^*$ ) prediction (Figure 8b) is not very good. The disagreement occurs because the predicted surface layer was more stable than was observed.  $Z^*$  increases almost linearly with increasing stability. Very large  $Z^*$  values were predicted at the end of the second period because it was stable and because the predicted well mixed humidity was too low, Figure 7a.

n) The predicted surface layer  $C_n2$  values (Figure 8c) were always less than those observed because of the previously mentioned inaccuracy in surface layer stability. Minima at 19/2300, 20/1800 and 20/0500 correspond to the surface layer being neutral as it passed from unstable to stable, unstable to stable and stable to unstable conditions, respectively.





i) The predicted surface layer aerosol scattering extinction for 8-12  $\mu\text{m}$  (Figure 3d) was very good during the second period. The observed and predicted decrease from 20/1800 to 21/1200 was associated with a decrease in relative humidity and wind speed. The wind speed used for the prediction was, of course, prescribed on the basis of observed results. Hence, the role of relative humidity on the extinction is that being evaluated.

#### C. PREDICTION INTERPRETATION AND APPLICATION

The demonstrated capability of this model, which is based on routinely observed input data, should be of assistance to the geophysics officer in estimating possible changes in the MABL and in the inversion and the potential impact upon tactically important parameters. Exploitation of the existing ducts is presently possible with IREPS. Specifically, the duct changes between elevated and surface based nature are of considerable concern to placement of platforms to enhance or to minimize communication links. Alerting commanders and airborne assets in advance to possible changes is a capability not previously available in on board assessment systems. Of additional use is the computation of the lifting condensation level to indicate the occurrence of clouds.



#### IV. CONCLUSIONS

The importance of and an approach for predicting evolutions of the marine atmospheric boundary layer have been described. Changes in the mixed layer depth strengths of overlying inversion and well-mixed properties lead to significant changes in the weapons/systems tactical environment. These include EM duct regions, optical turbulence and optical extinction, both within and at the boundaries of the inversion capped mixed layer.

Although the tactical descriptions are multi-variable and require detailed vertical descriptions, a simplified model based on routinely observed data appears to be quite useful for predicting changes over 12-18 hours. For a cloud topped period, it was demonstrated that the refraction, optical turbulence and optical extinction profiles were predicted quite well, as were cloud coverage changes.

The primary differences between observation and predictions were for the near surface layer and pertain to the evaporation duct height and the optical turbulence. The predicted evaporation duct was much too high and the predicted optical turbulence was much too low. In both cases, the predicted air temperature was too high (2-3 C) which resulted in a neutral to stable condition. The cause for this appears to be due to improper specification of



cloud cooling within the mixed layer. This is an area in which research is still being performed.

Two schemes are presently being evaluated for specification of cloud top cooling and entrainment, Stage and Businger (1981) and Deardorff (1976). Both address entrainment and cloud top cooling for short and long wave radiation, but large disparities exist in actual parameterization. More study in the variance of absorption with insolation and cloud buoyancy should resolve the difference. Both of these effects may have great impact on the predicted results because of the bulk nature of the model employed.

Tactical decisions can only be made with timely, pertinent and accurate information. The specific information presented by this model can be extremely important to temporal and spatial variation of ducting and refraction. As a bulk model, it is a gross approximation to actual conditions, but affords decision makers an estimation of most probable relevant changes in the meteorological conditions.



## APPENDIX A

### OPERATING PROCEDURES FOR THE MODEL PROGRAM

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## MODEL USAGE PROCEDURES

### 1. Model Components and Flowchart

Using this code requires minimal knowledge of microcomputer systems. Inputs required are an initial radiosonde (IREPS), forecast winds (up to 30 hours), and subsidence (divergence) and thermal advection. Because of forecasting, some ability to estimate large scale subsidence and advection is required.

#### 1.1 Model Components.

A block diagram and flow chart for the program appear in Fig. A-1 and A-2, respectively. The block diagram (Fig A-1) gives an overview of the program operation and flow, as broad as possible without specifics. The flow chart can be useful to keep track of position within the execution of the program. The program flow (Fig A-2) was designed to be as autonomous as possible, yet enable the user to interface with the procedure as deemed necessary. The two critical points in program flow are the input of subsidence and selecting an initial, simplified model for the atmospheric structure (digitizing).

The following sections include separate discussion of program operation, initial parameter input, selection of



output, and procedures for adjusting inputs to produce meaningful output.

## 1.2 Overview of Model Flow

The first list of items for selection is the DIRECTION MENU from which the user selects the operation to be performed. The operation can be to:

- 1) Predict the change of the inversion,
- 2) Display the predicted results, graphics or tabular form,
- 3) End prediction model and rewind tapes,
- 4) Return to IREPS,
- 5) Review or Change any initial conditions, then rerun the prediction model.

Any data set on an IREPS data tape can be called. The prediction would normally be the first choice in a procedure. In the prediction procedure (choice 1), the computation loop steps are:

- 1) Choose the IREPS data set,
- 2) Enter forecast winds and other initial conditions,
- 3) Approximate a stick structure to the temperature and specific humidity profiles from the selected IREPS data set.

Do not use IREPS bailout keys to correct errors.

EXCEPTION: User Defined Key 1 will take the user back to the DIRECTION MENU.



Once all the computations have been performed for a forecast period, the program will return to the DIRECTION MENU. If the display (2.3) is selected at this point, the user may select displays of various computed values. Selection may be of the inversion height change and 'M' profiles at spaced intervals or the inversion strength 'jumps' and well-mixed temperature and specific humidity or a tabular print out of the computed parameters. After each of these displays are completed, the program will return to the DISPLAY MENU for a choice of different display or return to the DIRECTION MENU.

The user may also use the DIRECTION MENU to choose a different value for subsidence or other parameters by going through the REVIEW/CHANGE MENU. The prediction model must be run after changes are made to produce new outputs.

In the following section we will consider the program steps, the block diagram should be used to follow the discussion.





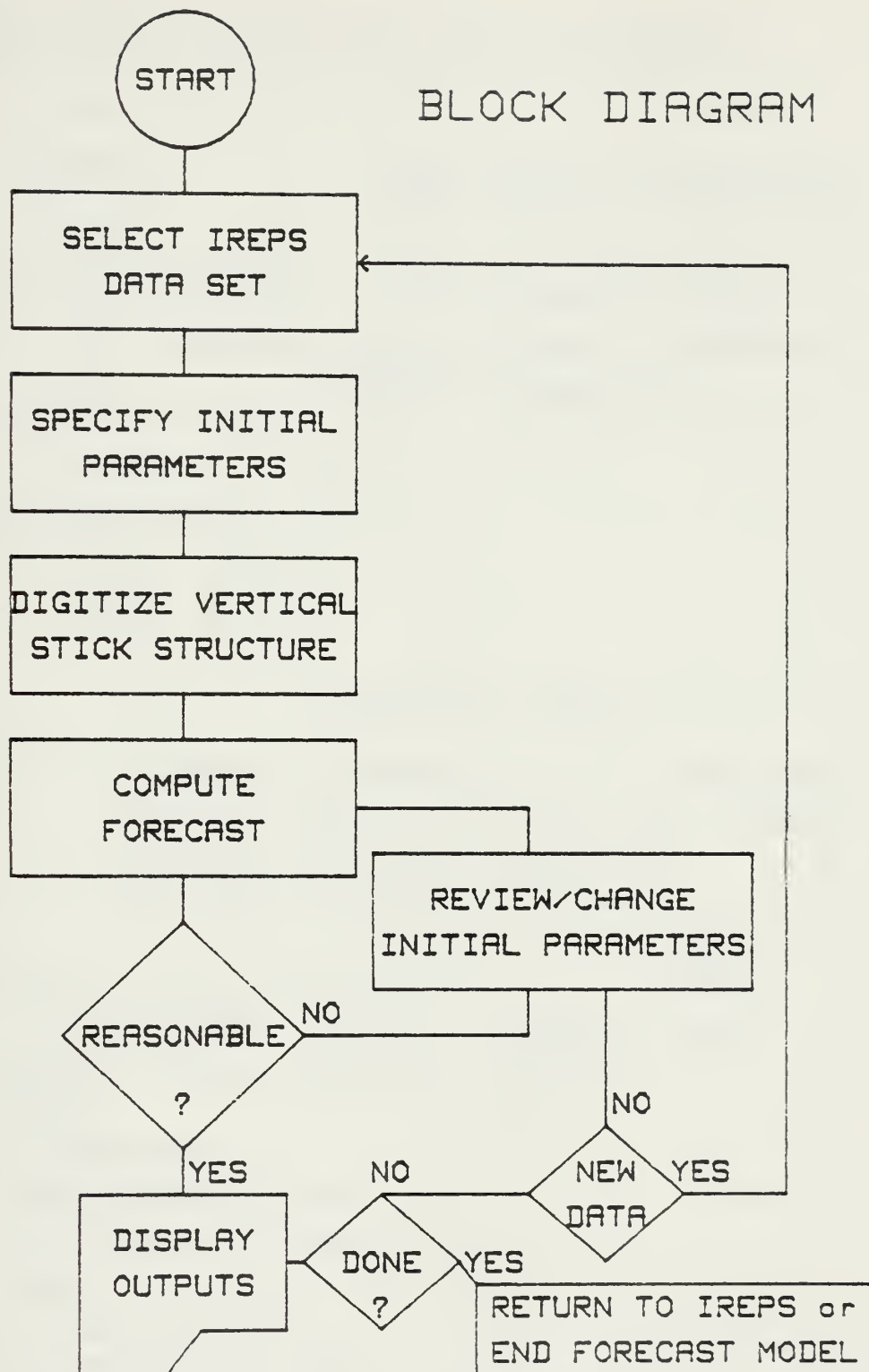


Fig. A-1. PROGRAM BLOCK DIAGRAM



# PREDICTION FLOW CHART

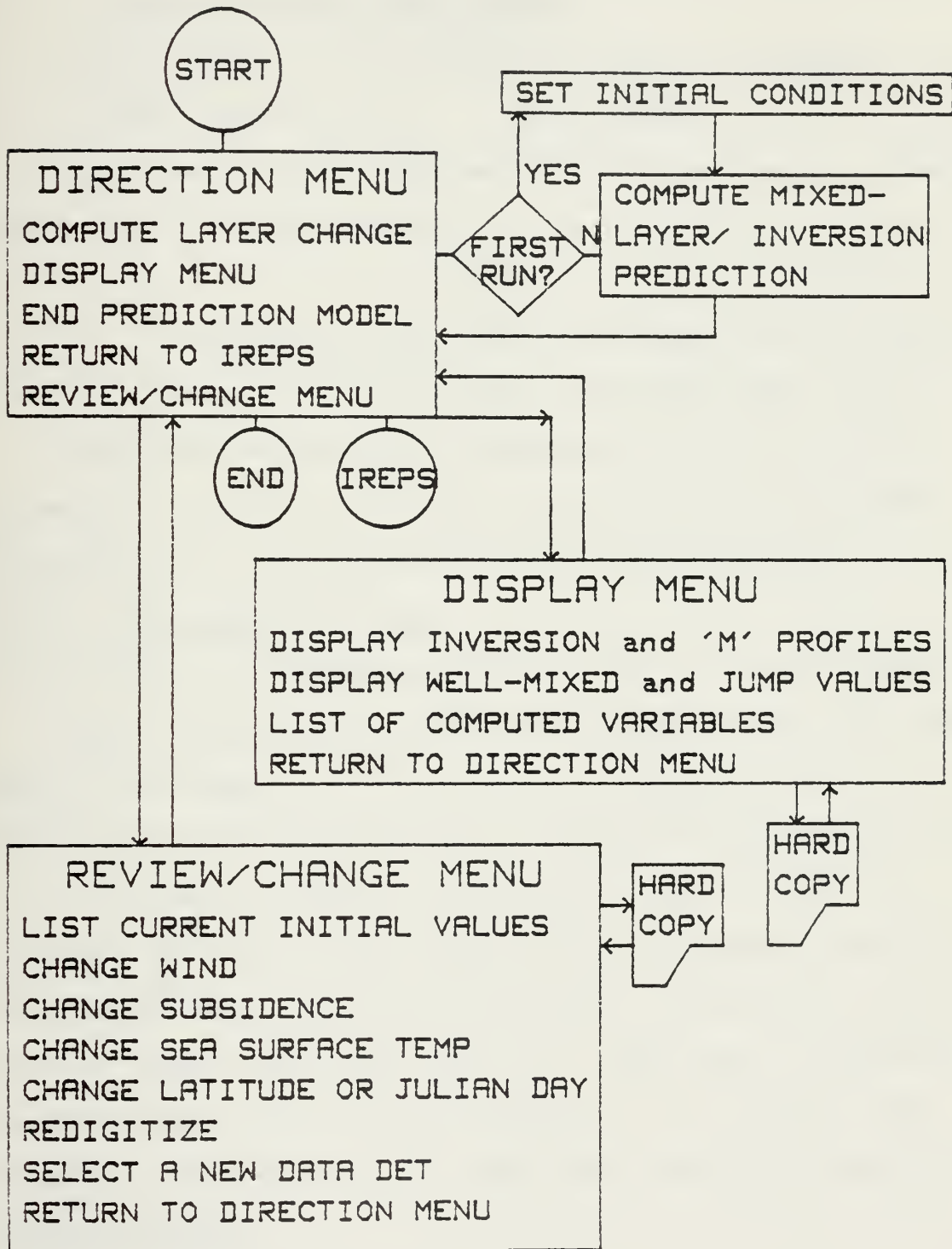


Fig. A-2. PROGRAM FLOWCHART



## 2. PROGRAM EXECUTION STEPS

### 2.1. Starting Procedures

#### 2.1.1 Loading and Starting Program

The prediction model program is loaded by typing:

LOAD "MIXED2:xxx",1        then EXECUTE

Where xxx is the proper mass storage device (e.g. T14) containing the model program.

#### NOTE

In default, the program will look for the data tape to be in the left hand tape drive (T14).

Questions requiring user response will be set off by asterisks, the selection menus can be viewed on the flow diagrams or at the beginning of each major section.

#### 2.1.2 Enter Execution Date

\*\*\*\*\*

ENTER Execution Date as date of forecast run, just press  
CONT if the same

\*\*\*\*\*

The entered date will be printed on all displays to indicate the date of run, this is not necessarily the date of the data set. If it is left blank, the date will default to that of the IREPS data set (i.e. IREPS date if IREPS has just been run, blank if this program is run alone.) The computer will then read the IREPS data table and display the DIRECTION MENU.



# DIRECTION MENU

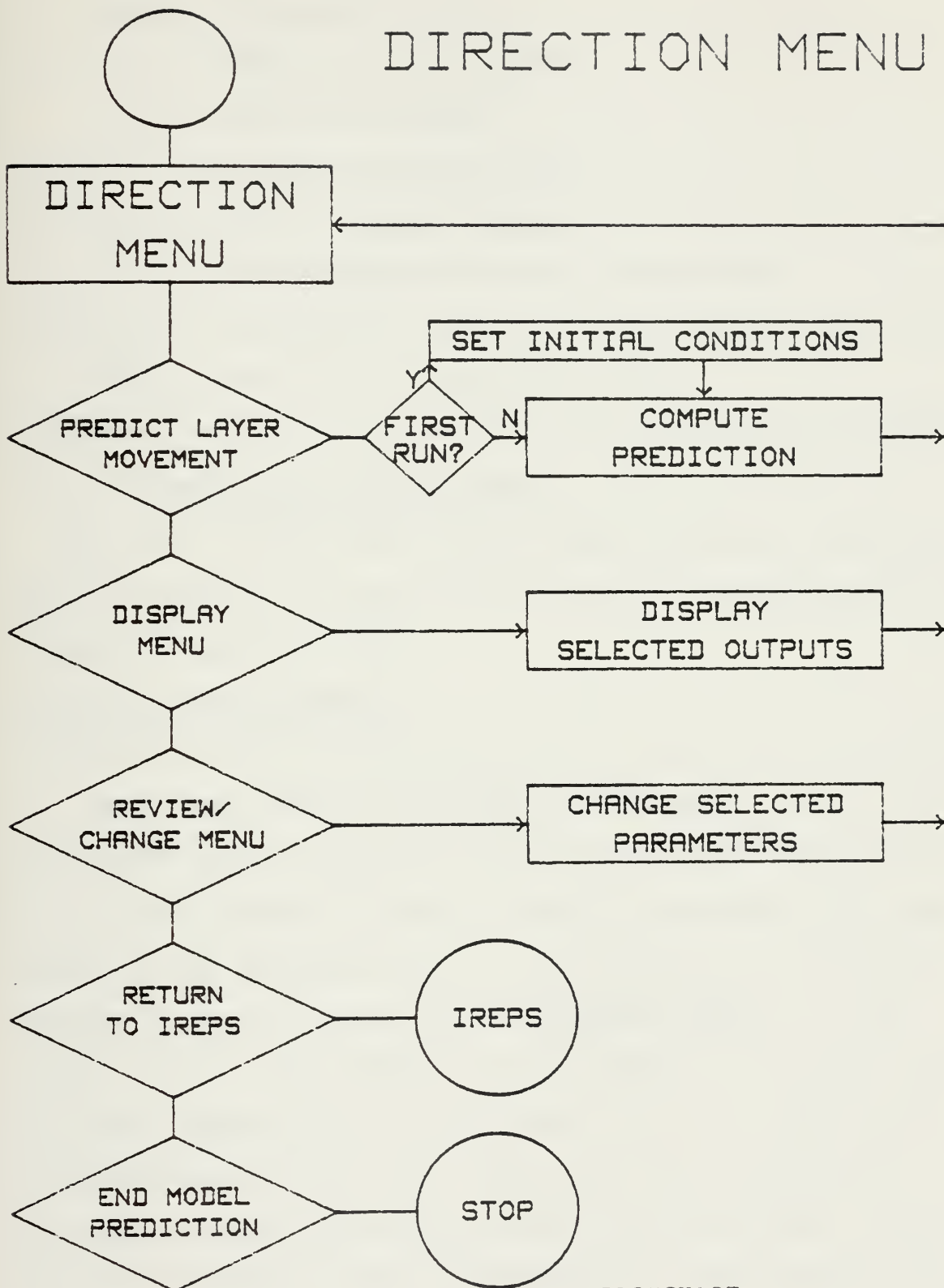


Fig. A-3. DIRECTION MENU FLOWCHART





## 2.2 DIRECTION MENU

Choices of procedures are:

- 1) COMPUTE THE LAYER CHANGE
- 2) DISPLAY THE OUTPUTS
- 3) END THE PREDICTION MODEL
- 4) RETURN TO IREPS PROGRAM
- 5) REVIEW/CHANGE ANY INITIAL CONDITIONS

\*\*\*\*\*

ENTER option (1 to 5) then press CONT

\*\*\*\*\*

### 2.2.1. COMPUTE THE LAYER CHANGE.

The list of data sets on the IREPS data tape is presented and the selection is made by entering the corresponding line number, followed by CONT.

#### 2.2.1.1. Data Set Choice

\*\*\*\*\*

ENTER THE NUMBER OF THE DATA SET DESIRED

\*\*\*\*\*

If the desired data set is not on the present data tape, hence is not displayed, SFK 1 (kl--top right of keyboard) should be used to return to the DIRECTION MENU, or type 'CONT Option', then EXECUTE. If a different data tape is to be used, insert it in the left tape drive and restart the program with STOP and RUN. Otherwise, the program will retrieve the entered choice of data set and proceed toward the next procedure which is digitizing. The program will



ask for winds (2.2.1.4.), subsidence (2.2.1.5.) and the sea surface temperature (2.2.1.6.).

#### 2.2.1.2 Latitude and Julian Day

The program uses these two inputs for calculating the zenith angle of the sun and thus the amount of insolation at the top of the inversion or cloud layer.

\*\*\*\*\*

ENTER Latitude of the prediction area [-90 to 90] [use - for South]

\*\*\*\*\*

ENTER the Julian day of the year [maximum 3 digits]

\*\*\*\*\*

#### 2.2.1.3 Beginning Time

\*\*\*\*\*

ENTER THE BEGINNING TIME [4 digits]

\*\*\*\*\*

The beginning time will be displayed on all the output. The entered time should be fairly close to the start time since it determines the beginning of the 30 hour forecast period. The entered time must have four characters (e.g. 1900). The program displays will only be in whole hour segments for easier graphic interpretation.

#### 2.2.1.4 Wind Forecast

\*\*\*\*\*

IS THIS WIND FROM IREPS OKAY (Y/N)?

\*\*\*\*\*



The program will display the initial time and the wind speed as previously entered in the IREPS data set. If the wind is to stay the same, press CONT with no entry, the response will default to the first of the options. If the wind is to be changed, enter 'N', press CONT, in which case the following question will ask for a new beginning wind speed.

\*\*\*\*\*

ENTER BEGINNING WIND SPEED [KNOTS] at time XXXX

\*\*\*\*\*

Winds are requested in KNOTS. The code performs computations with wind in m/s, a conversion is performed, (c.f. Appendix C.) The display is now set up to enter forecast winds for the period. (Fig B-1)

\*\*\*\*\*

hhmm,ww FROM THE FORECAST, ENTER: TIME,WIND (KNOTS)

\*\*\*\*\*

The maximum number of winds USED is 10. When done entering winds, enter 'E' or 'END'. Winds will be linearly interpolated between input times. This is a gross approximation, but works well with the degree of accuracy used in forecasting winds. To get a smoothing closer to the forecast, enter more winds at the times of rapid change. If the fine structure is available or needed only for the first part of the period, enter the winds as desired. If the last



wind entered is for a time before the end of the period it will be held constant to the end of the period.

If the initial wind is to be used throughout the period, enter 'E' or 'END' as the first response to this question. As a prompt, the time of the last possible input period, 30 hours after the beginning time, is displayed. All times must be entered sequentially, times beyond the last period will not be considered.

\*\*\*\*\*

DO THESE WINDS LOOK OKAY (Y/N)?

\*\*\*\*\*

If different winds are desired, the computer will ask for correction of entered winds, one line at a time. If the displayed winds are correct, press CONT, if not, enter N and refer to the previous question. The next requests will be for subsidence, and a check of sea surface temperature. The program flow will then proceed to digitizing.

#### 2.2.1.5. Subsidence Forecast

\*\*\*\*\*

ENTER SUBSIDENCE (m/sec) [First value=-.003 ], or CONT to use same value?

\*\*\*\*\*

Enter a value of subsidence in meters per second. This can be calculated from the divergence field, determined explicitly from the previously used value or by manipulating this model between successive soundings.





#### 2.2.1.6. Sea Surface Temperature Specification

\*\*\*\*\*

ENTER THE SEA SURFACE TEMP IN 'C or just CONT for same  
value

\*\*\*\*\*

The sea surface temperature from IREPS, which is displayed, may need refinement from the initially entered value. This would arise if the temperature used in the IREPS data set was the sea water injection temperature. To use the existing value, just press CONT without entering anything. To change the value, enter the new temperature in degrees centigrade, and press CONT.

#### 2.2.1.7 Profile Initialization

The program will now go to the digitizing, the determination of the vertical structure of potential temperature and specific humidity. The steps establish:

Inversion height

Potential temperature

(well-mixed, jump and lapse rate values)

Specific humidity

(well-mixed, jump and lapse rate values)

Previous inputs will be displayed on the plot. One display with data and digitized results appears in Fig.B-2. At the end the user will be asked to specify whether the plotting is OKAY or if he wants to do it AGAIN, if an error



is made during the digitizing routine, continue to this question, then redigitize.

The program will draw out the digitizing graph and its labels, then enter the digitizing mode. The first structure to plot will be the potential temperature, the second will be the specific humidity. The profile data, taken from the IREPS data tape, will be displayed to 2400 meters or the maximum height of entered data if less than 2400 meters. When digitizing can begin, the computer will beep and a full screen cursor will appear. To position the cursor, use the arrow keys at the top, center of the keyboard, then CONT.

#### NOTE

Finer structure is achieved by using shift when positioning the cursor. This will move it one pixel, or picture element, at a time.

#### 2.2.1.7.1. POTENTIAL TEMPERATURE: $\theta$

- 1a) Inversion Height: position the horizontal line at a representative inversion height (usually near the middle of the sharp temperature 'jump'.)
- 1b) well-mixed Temperature: position the vertical line at a representative value for the well-mixed temperature below the inversion, then CONT. POINT 1
- 2) Inversion 'jump': horizontally position the small cursor at the point where the



extension of the profile above the layer meets the horizontal 'jump' line at the inversion height (use precision eyeball), then CONT.

POINT 2

3) Gradient Above the Inversion: position the small cursor at the top of the screen or highest data point to get the best linear approximation of potential temperature above inversion, determining lapse rate, then press CONT. POINT 3

#### 2.2.1.7.2. SPECIFIC HUMIDITY: Q

1a) The inversion height determined for the potential temperature sequence will be the same for the specific humidity procedure. POINT 4

1b) Well-mixed Specific Humidity: position the vertical line at a representative value for the structure below the inversion, then CONT. POINT 4

2) Inversion 'jump': position the cursor where the extension of the profile above meets the horizontal 'jump' at the inversion (again, this is very subjective), then CONT. POINT 5

3) Gradient Above the Inversion: position the small cursor at the top of the screen or highest data point to get the best linear approximation of the specific humidity above the inversion, determining lapse rate, then press CONT. POINT 6



ENVIRON. DATA LIST, FROM MIXED2 NPS 05 20 78/0430

WIND 5.7 AIR TEMP 11.3  
SEA TEMP 15.0 REL HUM 97.7  
SFC PRESS 1013.1 IREPS EVAP DUCT HT 5.9

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.1	10.9	93.0	6.0	334	11.0	7.3
2	1000.0	10.7	93.0	114.7	347	11.3	7.2
3	972.0	9.0	93.0	351.2	372	12.4	6.4
4	954.0	11.1	22.0	506.7	353	16.1	1.7
5	947.0	18.4	20.0	568.9	360	24.0	2.5
6	944.0	18.9	20.0	596.0	363	24.7	2.6
7	923.0	19.4	19.0	789.0	387	27.1	2.6
8	950.0	14.9	24.0	1490.9	481	29.5	2.4
9	754.0	9.9	19.0	2494.7	609	34.3	1.4
10	700.0	7.8	19.0	3109.3	691	38.3	1.2

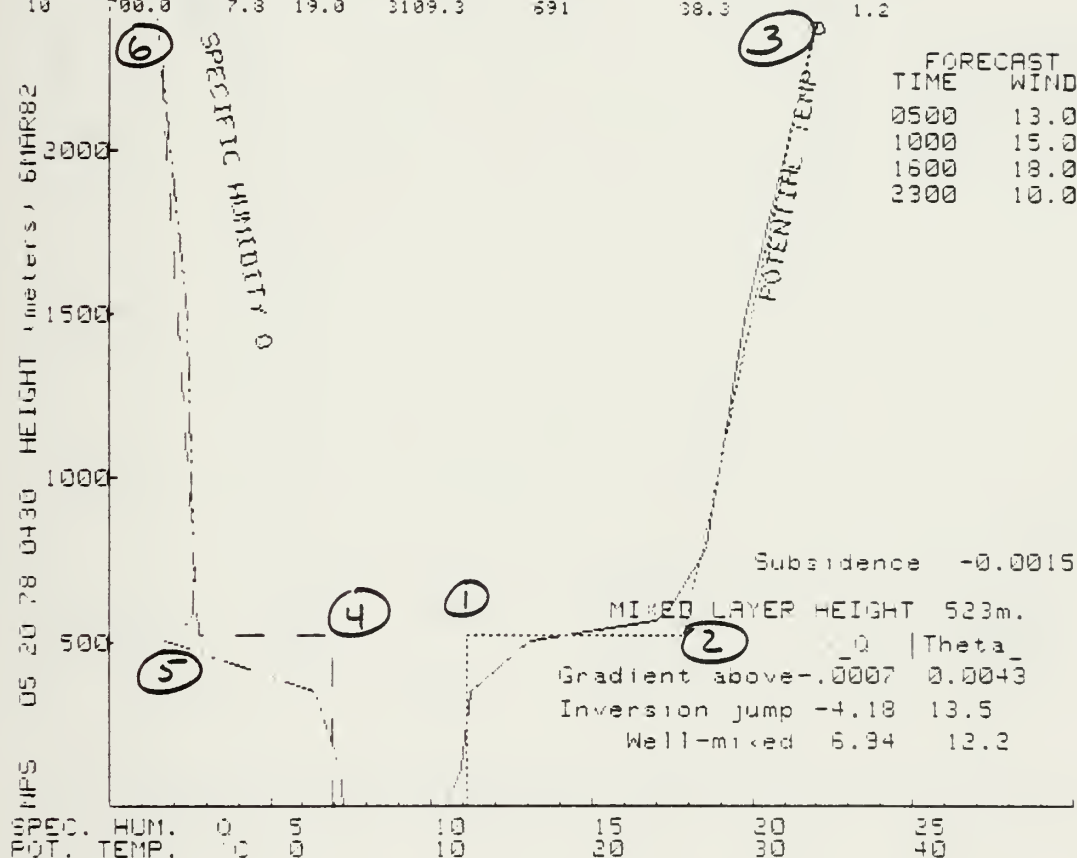


Fig. A-4. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE





ENVIRON. DATA LIST, FROM MIXED2

SCI

10 03 76 1400 SCI

WIND 5.1 AIR TEMP 23.9  
SEA TEMP 15.0 REL HUM 60.0  
SFC PRESS 1013.1 IPEPS EVAP DUCT HT 22.6

LEVEL	PRESS	TEMP	RH %	METERS	M UNITS	POTENT TEMP	SPEC HUM
1	1013.0	23.9	58.0	5.9	338	24.0	10.4
2	1000.0	19.9	70.0	118.2	354	21.1	9.8
3	976.0	16.5	83.0	326.3	382	19.7	9.4
4	954.0	14.9	79.0	520.3	399	20.0	8.0
5	929.0	14.9	56.0	745.9	410	20.2	5.7
6	907.0	15.7	53.0	949.2	435	25.0	5.7
7	879.0	14.4	41.0	1214.8	458	26.3	4.3
8	850.0	14.0	26.0	1497.9	484	28.7	2.5
9	807.0	12.9	10.0	1934.3	529	31.9	.9
10	765.0	11.1	10.0	2381.0	589	34.4	.8
11	717.0	8.4	10.0	2918.3	661	37.0	.7
12	700.0	8.2	10.0	3116.6	687	39.7	.7

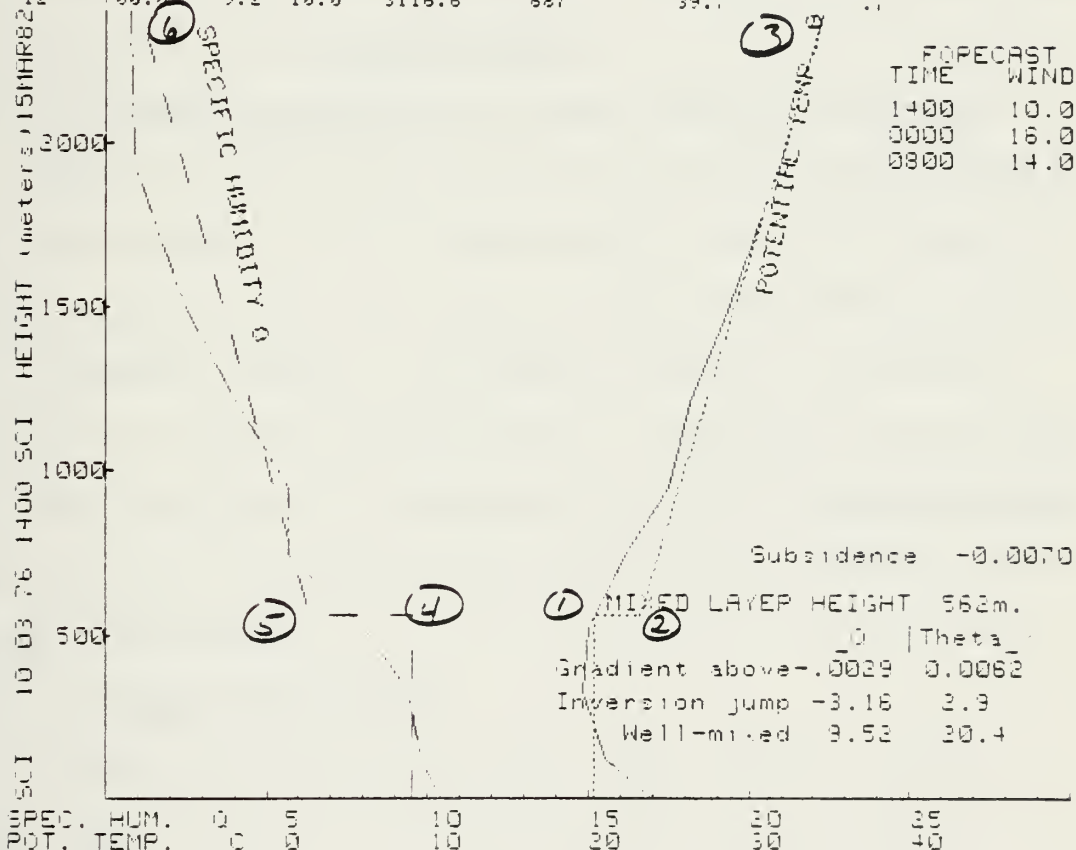


Fig. A-5. EXAMPLE OF DIGITIZED VERTICAL STRUCTURE



If the digitized plot is not as desired, move the cursor to AGAIN, press CONT, and begin with POTENTIAL TEMPERATURE (2.2.1.6.1). If the digitized plot is agreeable, move the cursor to the OKAY and press CONT. This will start the program into the computing stage. A picture of the layer computations is progressively displayed.

At the completion of the run the program will return to the DIRECTION MENU. The running prediction may be PAUSED at any time, then k1 or 'CONT Option', 'EXECUTE' will take the program back to the DIRECTION MENU.

#### 2.2.1.8. Change Subsidence or Other Initial Parameters

A decision point exists here as to the reasonableness of the layer movement. If it looks good, choose to display the change (2.2.2.). If the results of the computation do not go as expected, choose to re-compute using a new value of subsidence or other initial data, or redigitize the vertical structure. Both can be performed by choosing REVIEW/CHANGE MENU (2.2.5.). Use of the flow chart can be helpful when running the program.

#### 2.2.2. Display the Outputs

Selection of this option will take the user to the DISPLAY MENU for more defined and varied displays of computed inversion layer movement:

- 1) overall display of inversion movement and M-profiles
- 2) the inversion jumps of temperature and humidity



3) tabulation of selected values through the period

Refer to paragraph 2.3 DISPLAY MENU

#### 2.2.3. End Prediction Model and Rewind the Tapes

This choice will simply rewind the tapes in the computer and end the prediction model program. Remember to use the EJECT bar to remove tapes.

#### 2.2.4. Return to IREPS

This choice will take the user back to the IREPS program. The IREPS driver tape must be in the right hand tape drive, before pressing CONT, to load successfully.

#### 2.2.5. REVIEW/CHANGE MENU

This option is for rerunning the program with different values for initial data. This can also be used for going through the digitizing routine and retaining the winds that were input. When the end of the digitizing routine is reached, the user will again be given the choice of changing the digitized points. If all looks satisfactory, press CONT which will return the program to this menu. This procedure can be continued until a good approximation is generated.



# DISPLAY MENU

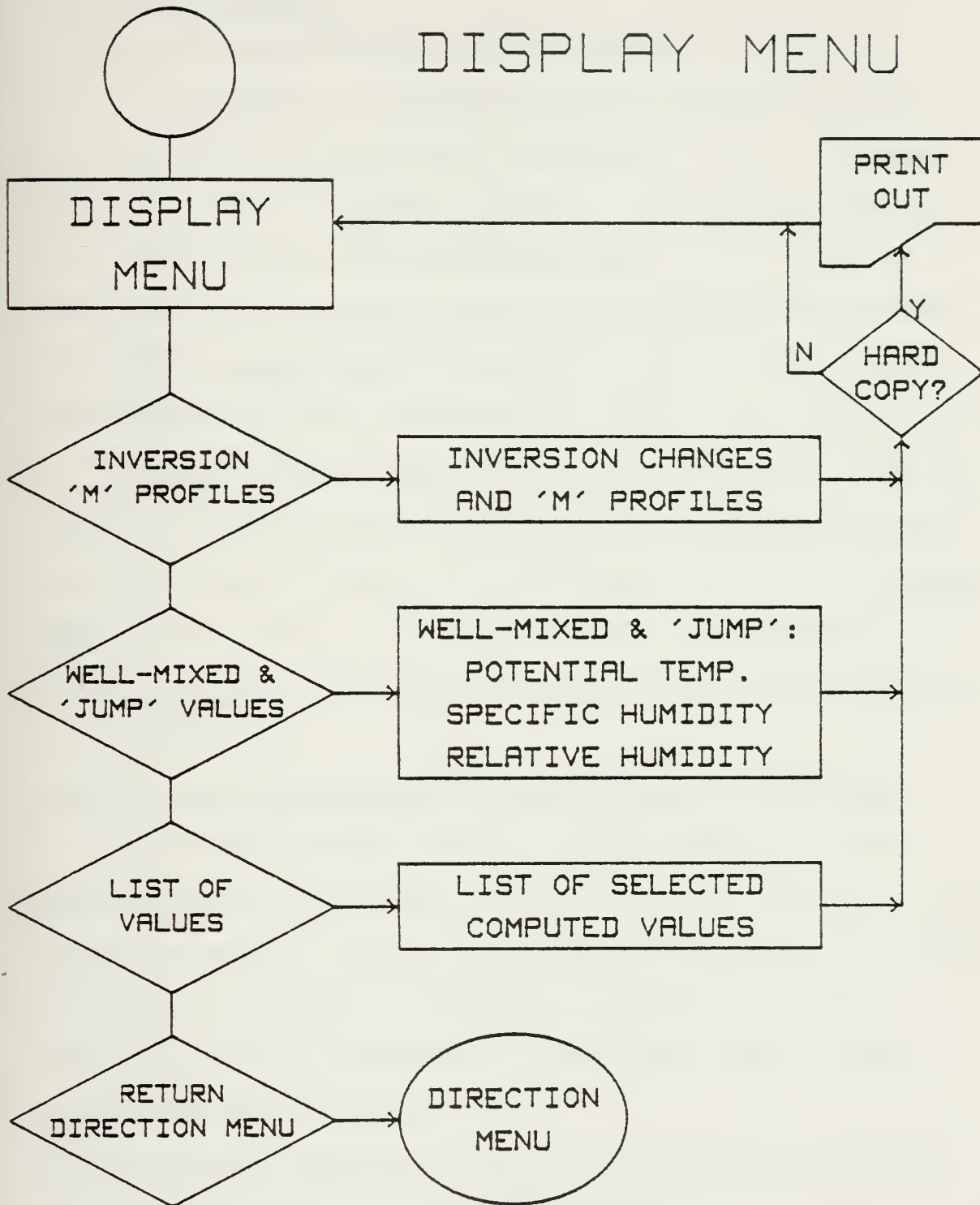


Fig. A-6. DISPLAY MENU FLOWCHART





### 2.3. DISPLAY MENU

The following options will be listed:

- |   |          |
|---|----------|
| 1 DISPLAY OF INVERSION AND 'M' PROFILES | graphics |
| 2 'JUMP' STRENGTH AT INVERSION          | graphics |
| 3 LIST OF COMPUTED VALUES               | tabular  |
| 4 RETURN TO THE DIRECTION MENU          |          |

\*\*\*\*\*

ENTER display choice then press CONT

\*\*\*\*\*

The user will be asked if he wants hard copy, after the graphics displays are drawn and before the tabular listing is run. Option 4 will take the program back to the DISPLAY MENU as will SFK 1 at any time. Further discussion and interpretation of the various aspects of the displays occurs in Appendix B.

#### 2.3.1. Graphics Display of Inversion and 'M' Profiles

As the main graphic product of the prediction, this display depicts the changes, over the 30 hour period, in the inversion height, the lifting condensation level (for cloud formation), the relative humidity and the 'M' profile (modified index of refraction) indicating elevated and surface based duct conditions.

#### 2.3.2 Graphic Display of Jumps and Well-Mixed Values of Potential Temperature and Specific Humidity

To illustrate the change in inversion strength, this display graphically shows the variations in the well-mixed



values next to the 'jump' values of both potential temperature and specific humidity. Also displayed is the relative humidity as it evolved through the forecast period.

#### 2.3.3 Tabular Display of Selected Parameters

This option lists the values that are stored during computation to be used for generating graphic displays. They are useful to more fully understand the movement of the inversion, the change in the duct area and the inversion strength.

#### 2.3.4 Return to the DIRECTION MENU

This option will return the program to the DIRECTION MENU for further choices to compute again, return to the IREPS program or just end the prediction model.



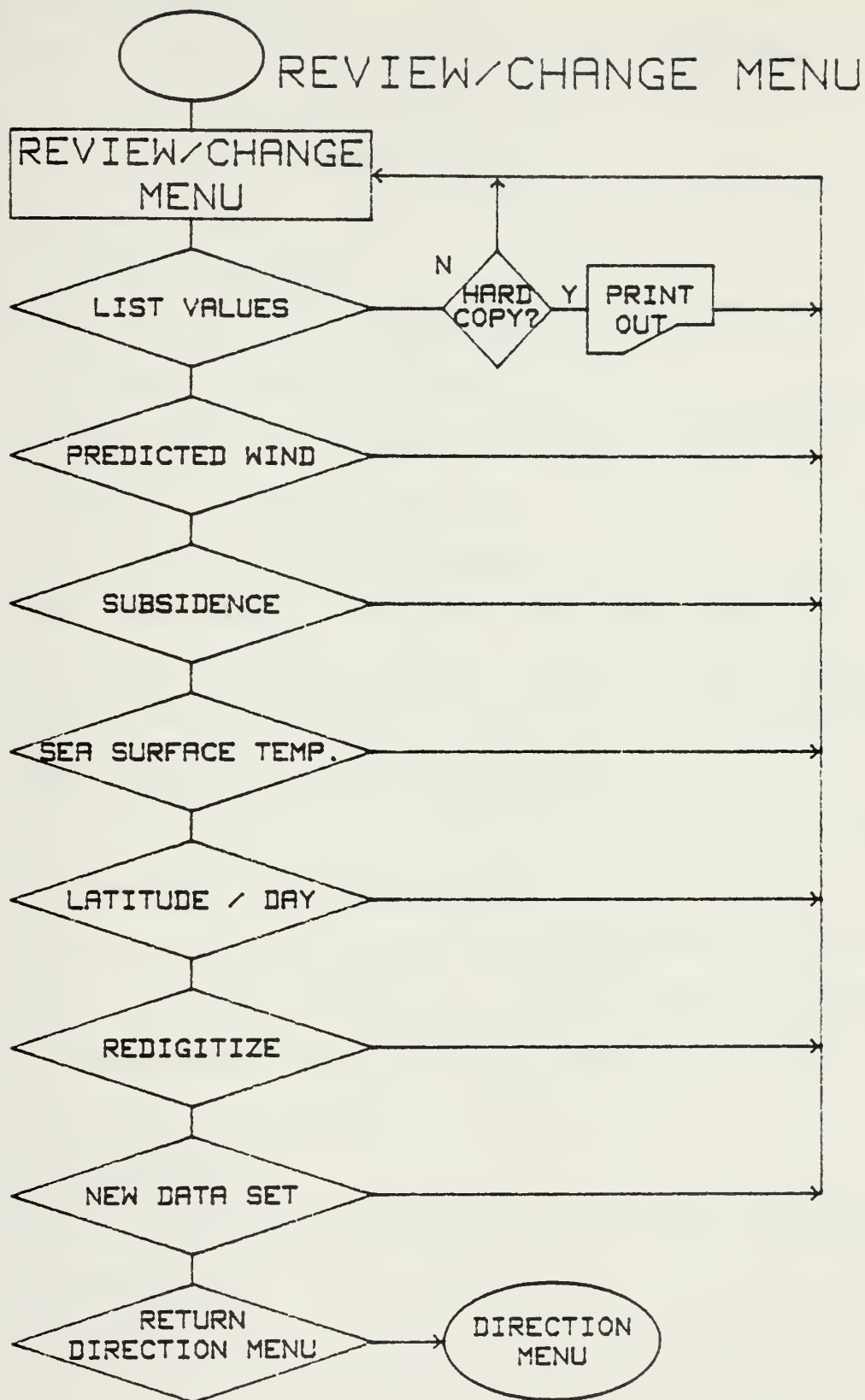


Fig. A-6. REVIEW/CHANGE MENU



## 2.4 REVIEW/CHANGE MENU

Select one of the following to change a parameter after which the prediction needs to run again:

- 1) List Current Initial Values
- 2) Change Wind
- 3) Change Subsidence
- 4) Change Sea Surface Temperature
- 5) Change Latitude or Julian Day
- 6) Redigitize the Vertical Structure
- 7) Select a different data set
- 8) Return to the DIRECTION MENU

Once this option is exercised, the model must run through another prediction before drawing out any displays.

\*\*\*\*\*

ENTER choice from REVIEW/CHANGE MENU (1-8)

\*\*\*\*\*

### 2.4.1. List Current initial Values

This will list the values of the indicated variables that were last used or modified. The user will be preempted to get a hard copy. Default of the question will be to the CRT, press CONT when ready.

### 2.4.2. Change Wind

Refer to procedure 2.2.1.3 and 2.2.1.4 and the return to REVIEW/CHANGE MENU.





#### 2.4.3. Change Subsidence

Refer to procedure 2.2.1.5, return to REVIEW/CHANGE MENU

#### 2.4.4. Change Sea Surface Temperature

Refer to procedure 2.2.1.6, return to REVIEW/CHANGE MENU

#### 2.4.5. Change Latitude or Julian Day

Refer to procedure 2.2.1.2, return to REVIEW/CHANGE MENU

#### 2.4.6. Redigitize the Vertical Structure

Refer to procedure 2.2.1.7, return to REVIEW/CHANGE MENU

#### 2.4.7. Select a New Data Set

Choosing a new data set will take the program through all the initial steps to set up the necessary parameters to make a prediction model run.

#### 2.4.8. Return to DIRECTION MENU

This option will return the program to the DIRECTION MENU for further choices to compute the forecast again, return to the IREPS program or end the prediction model.



## APPENDIX B

### PREDICTION OUTPUT

This appendix contains examples of the prediction output which are obtained by making selections from the DISPLAY MENU for output. Two different prediction runs are shown, each for a different observational period. The two periods were a cloud covered case, previously discussed in the body of the thesis, and a clear sky case, described by Davidson et al (to be submitted, JAM, 1982).

Entrainment energetics for the cloud covered case in this appendix were based on formulations by Stage and Businger (1981). Results for the same period were shown in the body of the thesis, but were based on a formulation by Deardorff (1976). The scope of this thesis was not to compare the differences between the entrainment parameterizations. Such a comparison will be performed separately by Naval Postgraduate School investigators.

Prediction output examples appear in two sets, one for each prediction period. Each set contains a listing of several computed variables and two pages with graphic plots of several computed variables and/or profiles. The plotted variables do not encompass all those listed. All selected outputs automatically appear on the CRT, and the printed copies (hard copy) may be obtained by selecting the appropriate option after CRT display.



The listing of predicted results (Fig. B-3 and B-6) are self-explanatory. The listed values are for every 30 minute period (the prediction time step) and the units are: velocity-m/s, temperature-Kelvin, height-m and humidity-g/kg.

The graphic plots contain information about the predicted vertical structure (Fig. B-1 and B-4) and the predicted values in the mixed-layer and at the inversion (Fig. B-2 and B-5).

The predicted vertical structure is presented in two panels in Fig. B-2 and Fig. B-4. The top panel shows predicted M profiles (Modified index of refraction) at 6 hour intervals, including possible surface based duct conditions. It is determined from the predicted well-mixed T and q and the predicted jumps at and lapse rates above the inversion. The bottom panel shows the top of the well mixed layer (-----), the top of the inversion zone (- - -) assuring an inversion thickness of .1 layer height and the lifting condensation level (.....). The lifting condensation level was computed from the well mixed temperature and specific humidity values. A description of duct determination appears at the bottom of the hard copy page.

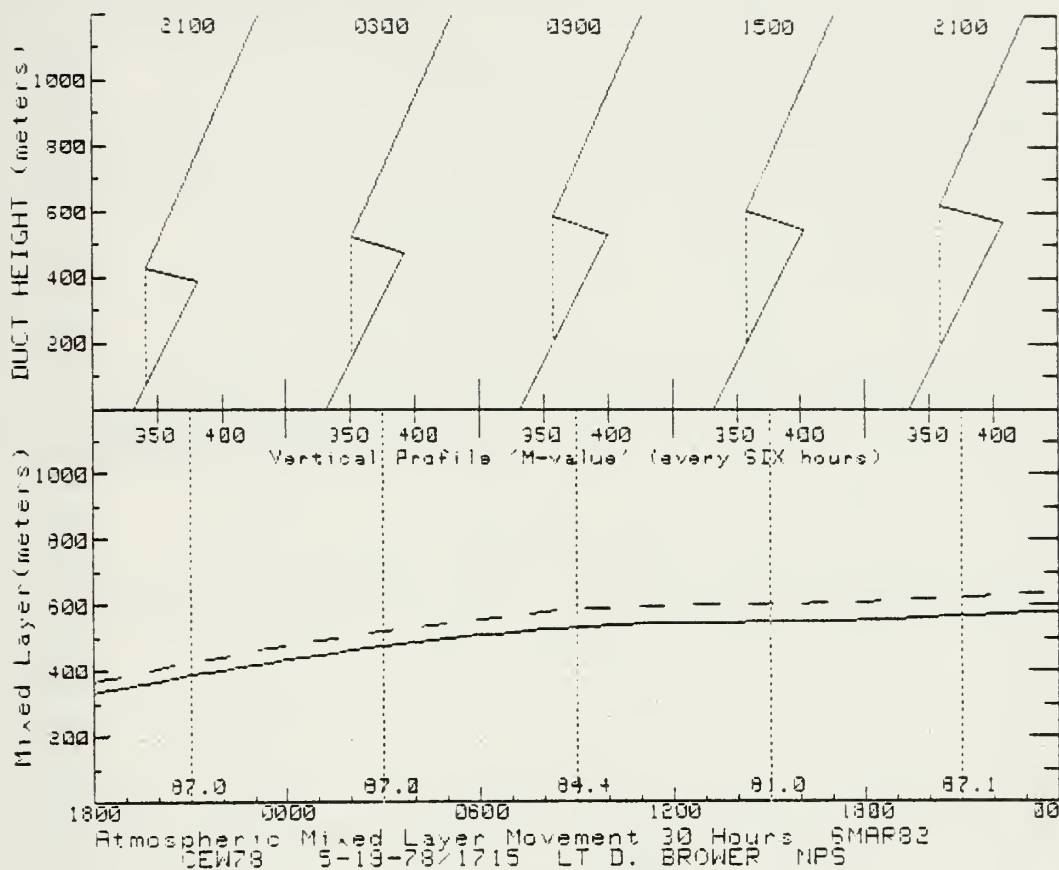
The graphic display of predicted values (Fig. B-2 and Fig. B-5) in the mixed layer and at the inversion are of several variables appearing in the listing option. The solid lines in the top panel represent the well mixed values



in the layer appropriate for the 10 meter level. The dashed lines are the 'jump' of that parameter (T or q) at the inversion. The 'jump' magnitudes are important in determining the strength of the duct and its depth. The bottom panel shows the relative humidity at the 10-meter level. It can be used to determine the proximity of fog or clouds and would be important in aerosol equilibrium size determination.







This is a SIMPLIFICATION of the real structure.

This display is divided into UPPER and LOWER windows:

LOWER WINDOW displays the top and middle of the elevated layer and its forecast continued movement for a thirty hour period after beginning.

At the bottom is the Relative Humidity at each six hour period.

The lightly dotted line is the lifting condensation level.

[With enough moisture near the inversion, this can be used as a flag for possible cloud formation, or for high mixed-layer humidity, near the surface, to forecast fog.]

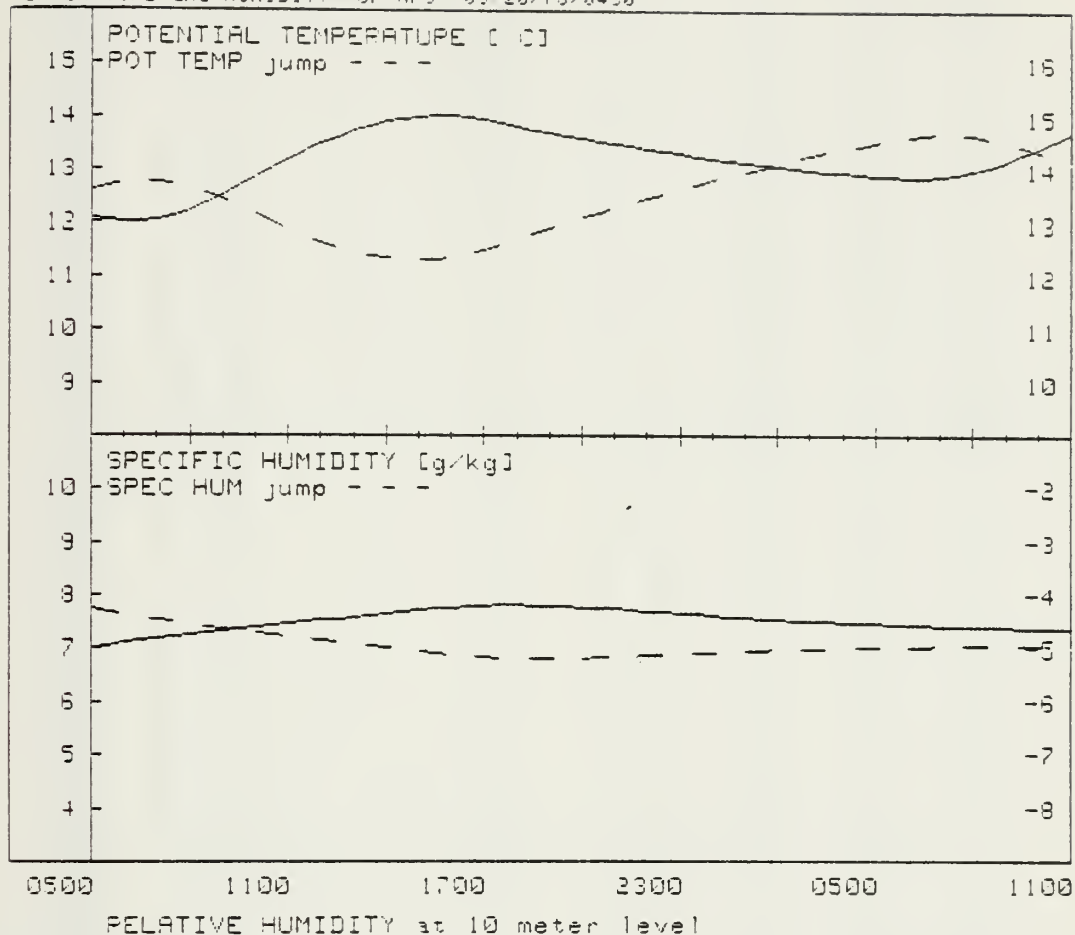
UPPER WINDOW picks out M-value structure (using only 4 points)

at each six hour period and will indicate a surface based duct only if the elevated M-value is less than or within 5 of the surface M-value. The sampled times are displayed at top.

Fig. B-1. Vertical Profile and 'M' Profiles- Cloudy Sky



TEMPERATURE and HUMIDITY for NPS 05/20/79/0430



30-HOUR PREDICTION OF POTENTIAL TEMPERATURE AND HUMIDITY  
 The well-mixed value scale is along the left, the 'jump' value  
 scale is along the right. The third frame is Relative Humidity.

Fig. 3-2. Mixed Layer and 'Jump' Values-Cloudy Sky

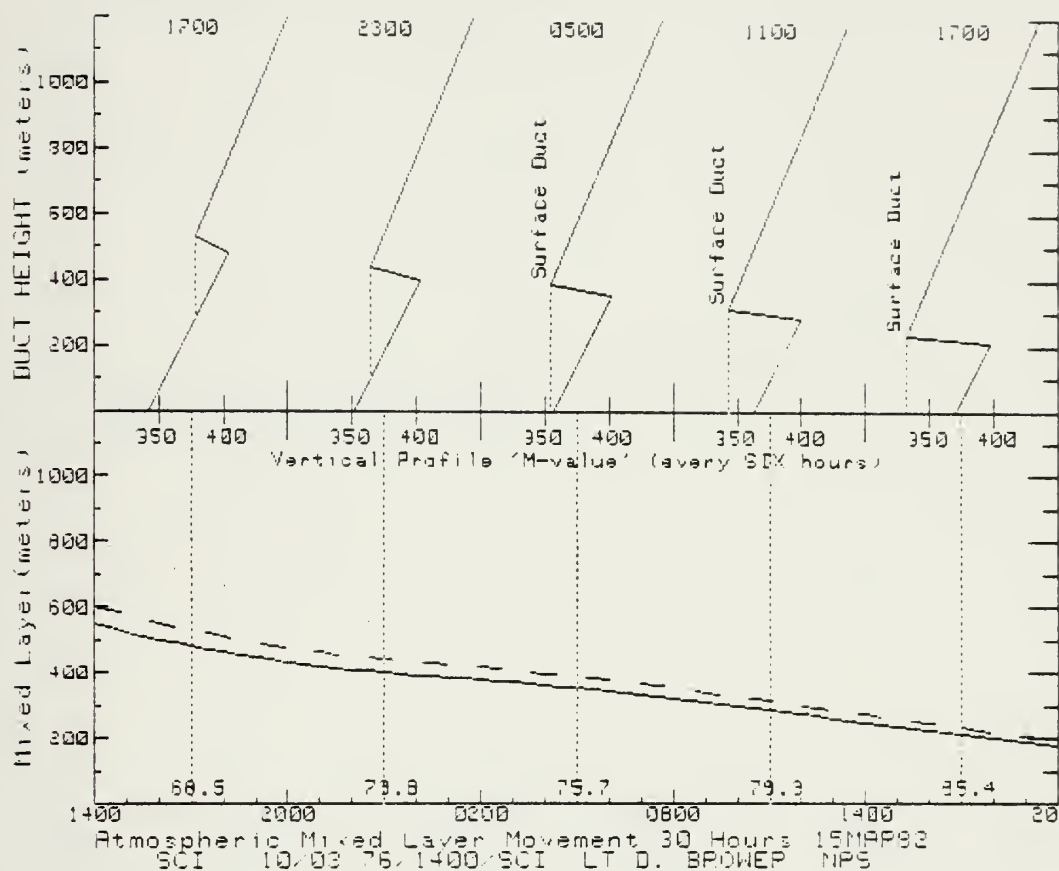


This is a list of plotted values. NPS 05.20/78/0430 2MAR82

HOUR	Cl	Clcl	RelHum	WIND	Th	Qp	Thu	Orh	Orhv	Qap
0500	526	380	79.7	6.7	12.1	7.0	13.3	13.6	12.9	-4.2
0530	530	352	80.6	6.8	12.0	7.1	13.3	13.7	12.9	-4.3
0600	534	330	81.4	6.9	12.0	7.1	13.2	13.8	13.0	-4.4
0630	539	312	81.9	7.0	12.0	7.2	13.3	13.8	13.0	-4.4
0700	544	301	82.1	7.1	12.1	7.2	13.3	13.8	13.0	-4.5
0730	549	296	82.1	7.2	12.1	7.2	13.4	13.7	12.9	-4.5
0800	555	297	81.9	7.3	12.2	7.3	13.5	13.6	12.9	-4.5
0830	560	301	81.6	7.4	12.4	7.3	13.5	13.5	12.7	-4.6
0900	566	310	81.1	7.5	12.5	7.3	13.8	13.4	12.6	-4.6
0930	571	320	80.6	7.6	12.7	7.4	14.0	13.3	12.5	-4.7
1000	577	333	80.1	7.7	12.9	7.4	14.1	13.2	12.3	-4.7
1030	582	346	79.5	7.9	13.0	7.4	14.3	13.0	12.2	-4.7
1100	587	359	79.0	8.0	13.2	7.5	14.5	12.9	12.0	-4.8
1130	591	371	78.6	8.1	13.3	7.5	14.7	12.8	11.9	-4.8
1200	596	382	78.2	8.2	13.5	7.5	14.8	12.6	11.8	-4.9
1230	600	392	77.9	8.4	13.6	7.6	14.9	12.5	11.7	-4.9
1300	605	400	77.6	8.5	13.7	7.6	15.1	12.5	11.6	-4.9
1330	609	406	77.5	8.6	13.8	7.6	15.2	12.4	11.5	-5.0
1400	614	410	77.4	8.8	13.9	7.7	15.2	12.3	11.5	-5.0
1430	618	412	77.4	8.9	14.0	7.7	15.3	12.3	11.4	-5.0
1500	623	411	77.5	9.0	14.0	7.7	15.4	12.3	11.4	-5.1
1530	627	409	77.7	9.1	14.0	7.7	15.4	12.3	11.4	-5.1
1600	632	405	78.0	9.3	14.0	7.8	15.4	12.4	11.5	-5.1
1630	638	399	78.3	9.0	14.0	7.8	15.4	12.4	11.5	-5.2
1700	643	392	78.6	8.7	14.0	7.8	15.3	12.5	11.6	-5.2
1730	649	383	79.0	8.4	13.9	7.8	15.3	12.6	11.7	-5.2
1800	655	374	79.4	8.1	13.8	7.8	15.2	12.7	11.8	-5.2
1830	662	366	79.7	7.8	13.8	7.8	15.1	12.8	11.9	-5.2
1900	668	358	79.9	7.5	13.7	7.8	15.1	12.9	12.0	-5.2
1930	675	352	80.1	7.2	13.6	7.8	15.0	13.0	12.1	-5.2
2000	682	348	80.2	6.9	13.6	7.8	14.9	13.1	12.2	-5.2
2030	689	345	80.3	6.6	13.5	7.8	14.9	13.2	12.3	-5.2
2100	696	343	80.4	6.3	13.5	7.7	14.8	13.3	12.4	-5.2
2130	702	341	80.4	6.0	13.4	7.7	14.8	13.4	12.5	-5.1
2200	709	340	80.4	5.7	13.4	7.7	14.8	13.5	12.6	-5.1
2230	715	339	80.4	5.4	13.4	7.7	14.7	13.6	12.7	-5.1
2300	721	339	80.4	5.2	13.3	7.7	14.7	13.6	12.8	-5.1
2330	727	339	80.4	5.2	13.3	7.6	14.6	13.7	12.8	-5.1
0000	733	338	80.5	5.2	13.2	7.6	14.6	13.8	12.9	-5.1
0030	739	338	80.5	5.2	13.2	7.6	14.5	13.9	13.0	-5.1
0100	745	338	80.5	5.2	13.1	7.6	14.5	14.0	13.1	-5.0
0130	751	337	80.5	5.2	13.1	7.6	14.4	14.1	13.2	-5.0
0200	756	337	80.5	5.2	13.1	7.5	14.4	14.1	13.3	-5.0
0230	762	337	80.5	5.2	13.0	7.5	14.4	14.2	13.3	-5.0
0300	767	337	80.5	5.2	13.0	7.5	14.3	14.3	13.4	-5.0
0330	773	337	80.5	5.2	13.0	7.5	14.3	14.3	13.5	-5.0
0400	778	337	80.5	5.2	13.0	7.5	14.3	14.4	13.5	-5.0
0430	783	337	80.5	5.2	12.9	7.5	14.2	14.5	13.6	-5.0
0500	789	337	80.5	5.2	12.9	7.5	14.2	14.5	13.7	-5.0
0530	794	337	80.5	5.2	12.9	7.4	14.2	14.6	13.7	-5.0
0600	799	337	80.4	5.2	12.9	7.4	14.2	14.6	13.8	-5.0
0630	804	338	80.3	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0700	809	341	80.0	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0730	814	346	79.7	5.2	12.9	7.4	14.2	14.7	13.8	-5.0
0800	818	354	79.3	5.2	13.0	7.4	14.3	14.7	13.8	-5.0
0830	823	364	78.8	5.2	13.1	7.4	14.4	14.6	13.7	-5.0
0900	827	376	78.2	5.2	13.2	7.4	14.5	14.5	13.7	-5.0
0930	831	390	77.6	5.2	13.3	7.4	14.6	14.5	13.6	-5.0
1000	836	405	76.9	5.2	13.4	7.4	14.7	14.4	13.5	-5.0
1030	838	422	76.3	5.2	13.5	7.4	14.8	14.3	13.4	-5.0
1100	842	439	75.6	5.2	13.7	7.4	15.0	14.2	13.3	-5.0
HOUR	Cl	Clcl	RelHum	WIND	Th	Qp	Thu	Orh	Orhv	Qap

Fig. B-3. List of Predicted Values-Cloudy SKY





The possibility of a surface based duct (SBD) is indicated and only due to the  $M'$  value greater at the surface than at the inversion height. Variation in the vertical structure must be emphasized when briefing this forecast in that a SBD may not exist.

This is a SIMPLIFICATION of the real structure.

This display is divided into UPPER and LOWER windows:

LOWER WINDOW displays the top and middle of the elevated layer and its forecast continued movement for a thirty hour period after beginning. At the bottom is the Relative Humidity at each six hour period. The lightly dotted line is the lifting condensation level.

[With enough moisture near the inversion, this can be used as a flag for possible cloud formation, or for high mixed-layer humidity, near the surface, to forecast fog.]

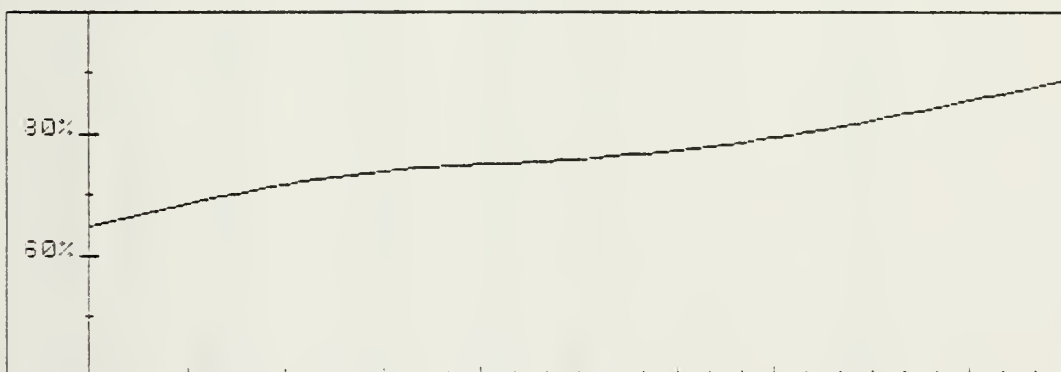
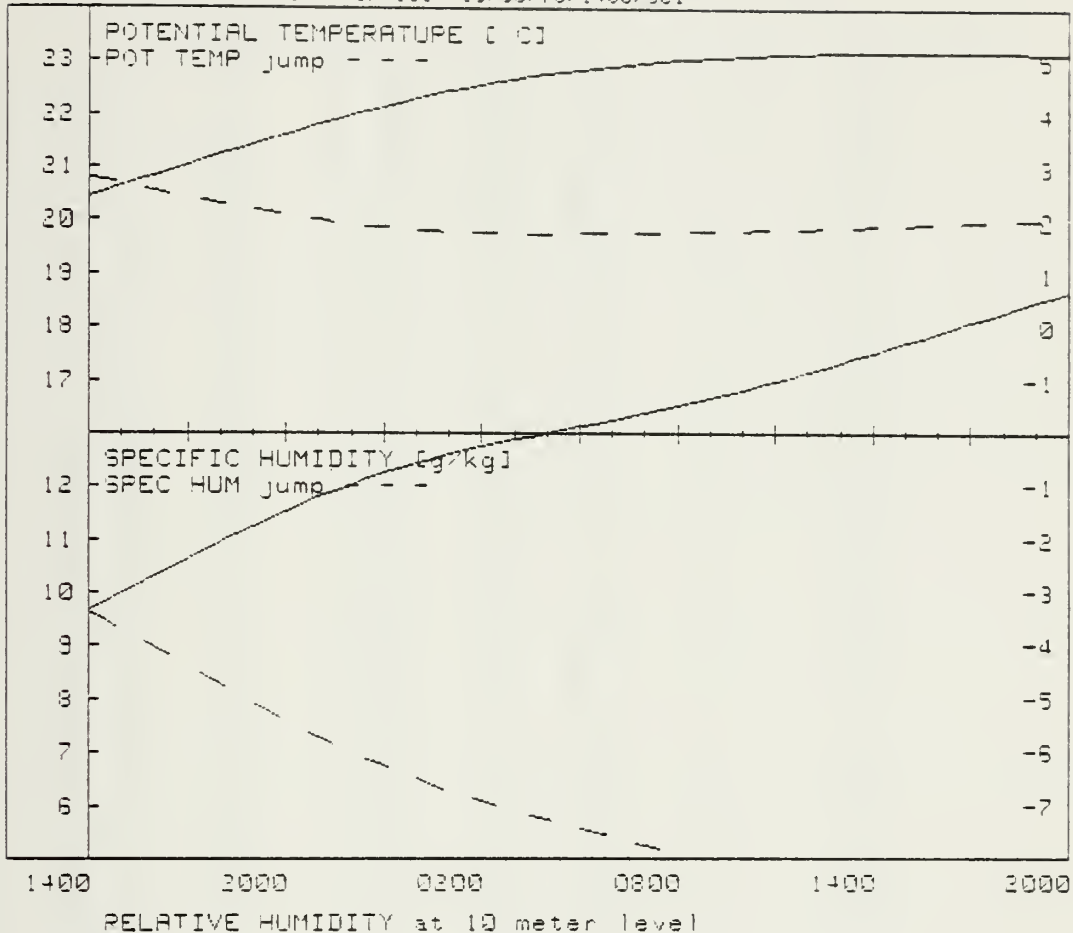
UPPER WINDOW picks out  $M$ -value structure (using only 4 points) at each six hour period and will indicate a surface based duct only if the elevated  $M$ -value is less than or within 5 of the surface  $M$ -value. The sampled times are displayed at top.

Fig. 3-4. Vertical Profile and 'M' Profiles- Clear Sky





TEMPERATURE and HUMIDITY for SCI 10/03/76/1400/SCI



30-HOUR PREDICTION OF POTENTIAL TEMPERATURE AND HUMIDITY  
The well-mixed value scale is along the left, the jump value  
scale is along the right. The third frame is Relative Humidity.

Fig. B-5. Mixed Layer and 'Jump' Values-Clear Sky



This is a list of plotted values. SCI 10/03/75/1400/SCI 15MAP82

HOUP	Zi	Zic1	RelHum	WIND	Th	Qp	Thu	Dth	Dthu	Dqp
1400	549	806	64.7	5.1	10.4	9.7	22.2	2.8	2.2	-3.3
1430	536	787	65.3	5.3	20.5	9.8	22.3	2.7	2.1	-3.5
1500	524	768	66.0	5.5	20.6	10.0	22.4	2.7	2.0	-3.7
1530	512	750	66.6	5.6	20.7	10.2	22.6	2.6	1.9	-3.9
1600	501	732	67.2	5.8	20.8	10.3	22.7	2.6	1.8	-4.0
1630	491	714	67.9	5.9	20.9	10.5	22.8	2.5	1.7	-4.2
1700	481	697	68.5	6.1	21.0	10.6	22.9	2.4	1.6	-4.4
1730	472	681	69.1	6.2	21.1	10.8	23.1	2.4	1.5	-4.6
1800	463	665	69.6	6.4	21.2	10.9	23.2	2.3	1.5	-4.7
1830	454	650	70.2	6.5	21.3	11.1	23.3	2.3	1.4	-4.9
1900	447	635	70.7	6.7	21.4	11.2	23.4	2.2	1.3	-5.1
1930	439	622	71.2	6.9	21.5	11.4	23.6	2.1	1.2	-5.2
2000	432	609	71.7	7.0	21.6	11.5	23.7	2.1	1.1	-5.4
2030	426	597	72.1	7.2	21.7	11.7	23.8	2.0	1.0	-5.6
2100	420	586	72.5	7.3	21.8	11.8	23.9	2.0	1.0	-5.7
2130	414	575	72.9	7.5	21.9	11.9	24.0	2.0	.9	-5.8
2200	409	566	73.2	7.6	22.0	12.0	24.1	1.9	.8	-6.0
2230	404	558	73.5	7.8	22.1	12.1	24.2	1.9	.8	-6.1
2300	400	550	73.8	7.9	22.1	12.2	24.3	1.9	.7	-6.3
2330	396	544	74.0	8.1	22.2	12.3	24.4	1.8	.7	-6.4
0000	392	538	74.2	8.2	22.3	12.4	24.5	1.8	.6	-6.5
0030	389	533	74.4	8.2	22.4	12.5	24.6	1.8	.6	-6.6
0100	385	528	74.6	8.1	22.4	12.6	24.7	1.8	.6	-6.7
0130	382	524	74.7	8.1	22.5	12.7	24.8	1.8	.6	-6.8
0200	379	521	74.8	8.0	22.6	12.7	24.9	1.8	.5	-6.9
0230	374	518	75.0	7.9	22.6	12.8	24.9	1.8	.5	-7.0
0300	371	515	75.1	7.9	22.7	12.9	25.0	1.8	.5	-7.1
0330	366	511	75.3	7.8	22.7	12.9	25.1	1.7	.5	-7.2
0400	362	508	75.4	7.7	22.8	13.0	25.1	1.7	.4	-7.3
0430	358	504	75.6	7.7	22.8	13.1	25.2	1.8	.4	-7.3
0500	353	500	75.7	7.6	22.9	13.1	25.2	1.8	.4	-7.4
0530	348	496	75.9	7.5	22.9	13.2	25.3	1.8	.4	-7.5
0600	343	491	76.1	7.5	22.9	13.3	25.3	1.8	.4	-7.6
0630	338	486	76.4	7.4	23.0	13.3	25.4	1.8	.4	-7.7
0700	333	480	76.6	7.3	23.0	13.4	25.4	1.8	.4	-7.7
0730	327	474	76.9	7.3	23.0	13.5	25.4	1.8	.4	-7.8
0800	321	467	77.2	7.2	23.0	13.5	25.5	1.8	.4	-7.9
0830	316	460	77.5	7.2	23.1	13.6	25.5	1.8	.3	-8.0
0900	310	453	77.8	7.2	23.1	13.7	25.5	1.8	.3	-8.1
0930	304	445	78.1	7.2	23.1	13.7	25.6	1.8	.3	-8.2
1000	298	436	78.5	7.2	23.1	13.8	25.6	1.8	.3	-8.3
1030	292	427	78.9	7.2	23.1	13.9	25.6	1.8	.3	-8.4
1100	286	417	79.3	7.2	23.1	14.0	25.7	1.8	.3	-8.4
1130	279	407	79.7	7.2	23.2	14.1	25.7	1.8	.3	-8.5
1200	273	397	80.2	7.2	23.2	14.2	25.7	1.8	.3	-8.6
1230	267	386	80.6	7.2	23.2	14.2	25.7	1.8	.3	-8.7
1300	261	374	81.1	7.2	23.2	14.3	25.8	1.9	.3	-8.8
1330	255	363	81.6	7.2	23.2	14.4	25.8	1.9	.3	-8.9
1400	248	351	82.1	7.2	23.2	14.5	25.8	1.9	.3	-9.0
1430	242	339	82.6	7.2	23.2	14.6	25.8	1.9	.3	-9.1
1500	236	326	83.2	7.2	23.2	14.7	25.9	1.9	.3	-9.2
1530	230	313	83.7	7.2	23.2	14.8	25.9	1.9	.2	-9.3
1600	224	300	84.3	7.2	23.2	14.9	25.9	1.9	.2	-9.4
1630	218	287	84.8	7.2	23.2	15.0	25.9	2.0	.2	-9.5
1700	212	274	85.4	7.2	23.2	15.1	25.9	2.0	.2	-9.6
1730	206	260	86.0	7.2	23.2	15.2	25.9	2.0	.2	-9.7
1800	200	247	86.5	7.2	23.2	15.3	25.9	2.0	.2	-9.8
1830	194	234	87.1	7.2	23.2	15.4	26.0	2.0	.2	-9.9
1900	188	221	87.7	7.2	23.2	15.5	26.0	2.0	.2	-10.0
1930	182	207	88.2	7.2	23.2	15.6	26.0	2.0	.2	-10.1
2000	177	195	88.8	7.2	23.2	15.7	26.0	2.0	.2	-10.2
HOUP	Zi	Zic1	RelHum	WIND	Th	Qp	Thu	Dth	Dthu	Dqp

Fig. 3-6. List of Predicted values-Clear Sky



## APPENDIX C:

### TERMS USED IN THE DISCUSSION AND PROGRAM:

Cn2 ... Index of refraction structure function parameter

[m<sup>-2/3</sup>]

Extinction ... loss of EM/EO energy due to absorption/  
scattering by species (molecules/aerosols) in the path.

Lifting Condensation Level ... Level at which a parcel will  
reach saturation if cooled while undergoing lifting.

Mixed Layer ... That part of the boundary layer where  
turbulent mixing has destroyed the gradients of  
conservative quantities.

Mixing Ratio ... the ratio of the water-vapor density to the  
density of the dry air.

Potential Temperature ... the temperature that an air parcel  
would assume if its pressure were changed by a  
dry-adiabatic process to some standard pressure.

Relative Humidity ... the ratio of vapor pressure to  
saturation vapor pressure times 100. Vapor in  
equilibrium with sea water is assumed to have a  
relative humidity of 98 per cent.

Specific Humidity ... the ratio of water-vapor density to  
total density and is usually designated by q.

Subsidence ... a sinking of air from high to low levels. The  
causes of its occurrence are dynamic, such as the  
frictional outflow of air near the surface associated



with high-pressure systems, the divergence of air from near the surface high pressure centers, and the divergence of air due to change in latitude as an air mass moves from north to south. (conservation of absolute vorticity)

Thermal wind ... vector wind change with height due to horizontal temperature gradient. This implies advection above the inversion.

Conversion ... KNOTS = (m/s) \* 1.94

$$1.94 = \frac{\text{ft}}{\text{m}} * \frac{\text{Nm}}{\text{m}} * \frac{3600\text{sec}}{\text{Hour}}$$





```

5  ! *****
10 ! ***          FOR TIE TO IREPS DATA PREDICTION          ***
15 ! ***    LT DAVID A. BROWER, USN, NPS, MONTEREY, CA.    ***
20 ! *****
25 ! BASIC DAVIDSON MODEL 'MIXED2'                                MARCH 30
30 ! REVISED CHRIS FAIRALL ENTRAINMENT COMPUTATION  11JAN82
31 ! NOW INCLUDING LONG AND SHORT WAVE RADIATION
    13JAN82
35  EXIT GRAPHICS !                                UPDATED:  19 MAR 82
40  GCLEAR
45  OPTION BASE 1
50  NORMAL
55  OFF ERROR
60  PRINTER IS 0
65  PRINT CHR$(27)&"&l32T"
70  PRINTER IS 16
75  Mass$=":T14"      ! CHANGE HERE FOR A NEW MASS STORAGE
80  GOTO 155
85  ! THE FIRST LINE FOR 'COM' NEEDED ONLY FOR 2.0
90  ! COM Irprog$,Irdats$,Rev$,Date$,Prints$,Perforated,
    Date_wanted
95  COM Names$(24),Loc$(24),Time$(24),Type$(1),Height$(1),
    Evap$(1)
100 COM Wmo$(30)[11],Wmont$(5)
105 COM SHORT Presur(30),Temper(30),Relhum(30)
110 COM SHORT Height(30),Munits(30),Nunits(30)
115 COM SHORT Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
    Change,Recenv
120 COM SHORT Coml(32,4),Envssq(16),Syssq(32),Lossq(32)
125 COM Envnam$(16)[24],Sysnam$(32)[24],Losnam$(32)[24]
130 ! COM Overlay$(24),Option$(80)
135 ! COM Nrec,Unprotected
140 ! DIM Dummy$(160),Errm$(80)
145 ! DIM Dlabel$(80),Default$(80),Doptions$(80)
150 ! DIM Next_overlay$(24)
155 DIM WindIn(10,2),Stick$(3),Frame_loc$(24),Frame_date$(
    24)
160 INTEGER J
165 DIM Pot_temp(30),Spec_hum(30),Zsnd(30),L$(160)
170 Julday=150
175 Lat=33
180 SHORT G(63,7)
185 RESTORE 190
190 READ Z,Zot,Kkk,Alpha_t,Deltim,Stick$(*) ! Alpha t is
    the ratio of heat to
195 DATA 10,5E-5,.35,1.35,1800      !      momentum transfer
    at Psi=0 [from BULK]
200 DATA "Gradient above","Inversion jump","      well-
    mixed"
205 Wsl=ws=-.003 !TO SET A TYPICAL DEFAULT
210 PRINT PAGE,"THIS IS 'MYREPS' WHICH MODELS THE CHANGE

```



```

      IN THE MIXED LAYER"
215  PRINT TAB(18),"ABOVE THE SURFACE";          !
      REV:18NOV80
220  Start: Tday$=Date$
225  IF (Tday$="") OR (Tday$=" ") THEN Tday$=" 6MAR82"
230  DISP CHR$(7);"ENTER Today's Date, THEN press
      'CONT'";
235  INPUT Tday$
240  PRINT Tday$
245  GOSUB Ireps_data
250  ! MINIMUM FREQ TRAPPED IN HERTZ= 3.6033E11*d(-3/2)  d
      DUCT THICKNESS IN m.
255  Option: ! TO WORK WITH THE IREPS KEYS
260  Menu: PRINTER IS 16
265  Aa=0
270  PRINT USING "@,K,2/,K";"This is the DIRECTION MENU",
      "Select option below, ENTER NUMBER and PRESS
      'CONT'."
275  PRINT USING "#,2/,2(10X,K,2/)";"1 COMPUTE NEW
      LAYER(displayed as computed on CRT)","2 PLOT of
      LAYER CHANGES "
280  PRINT USING "3(10X,K,2/),K";"3 END 'MIXED2'
      Program","4 RETURN TO IREPS OPTION LIST PROGRAM (
      with IREPS driver in T15)","5 REVIEW/CHANGE MENU"
285  INPUT "Enter Option(1 to 5) then press CONT",Aa
290  IF NOT ((Aa=1) OR (Aa=2) OR (Aa=3) OR (Aa=4) OR (Aa=5)
      ) THEN Menu
295  IF Aa=4 THEN Menu      !      LOAD "IREPS:T15",Input
      ! PUT IN LATER
300  ON Aa GOTO Start_out,Picture,Bye,Menu,Revchange
      !Subsidence
305  GOTO Menu
310  Start_out: IF Flag_rev THEN Run
315  Start_out_again: GOSUB Disp_data
320  GOSUB Jullat
325  GOSUB Enter_winds
330  GOSUB Subsidence
335  GOSUB Sea_temp
340  GOSUB Plt_struct
345  GOTO Run
350  Revchange: PRINTER IS 16      ! TO ENTER ANY CHANGES
      OR REVIEW DATA
355  Rc$="0"
360  IF NOT Flag_data THEN Menu      ! RETURN TO DIRECTION
      MENU IF NO DATA SET
365  Flag_rev=1      ! TO FLAG A RUN THROUGH THE REVISION
      ROUTINE
370  PRINT USING "@,K,/";"This is the REVIEW/CHANGE MENU"
375  PRINT USING "#,/,4(10X,K,2/)";"1 LIST CURRENT
      INITIAL VALUES","2 CHANGE WIND","3 CHANGE
      SUBSIDENCE","4 CHANGE SEA SURFACE TEMPERATURE"

```



```

380 PRINT USING "#,/3(10X,K,2/);"5 CHANGE JULIAN DAY
    or LATITUDE","6 REDIGITIZE VERTICAL STRUCTURE","7
    SELECT NEW DATA SET"
385 PRINT USING "10X,K";"8 RETURN TO DIRECTION MENU"
390 INPUT "Enter Option(1 to 8) then press CONT",Rc$
395 PRINT PAGE
400 IF (NUM(Rc$)<49) OR (NUM(Rc$)>56) OR (LEN(Rc$)<>1)
    THEN Revchange
405 IF VAL(Rc$)=7 THEN Start_out_again
410 IF VAL(Rc$)=8 THEN Menu
415 ON VAL(Rc$) GOSUB List_curr,Enter_winds,Subsidence,
    Sea_temp,Jullat,Plt_struct,Disp_data,Menu
420 GOTO Revchange
425 List_curr: GOSUB Hard_output
430 IF Hd$="Y" THEN PRINTER IS 0
435 PRINT "THESE ARE THE LATEST VALUES FOR THE PREDICTION
    MODEL"
440 PRINT USING "/,K";"DATA SET: "&Loc$&" "&Time$
445 PRINT USING "/K,X3D,2X9A,M2D,2/,K,M.5D,8X,K,2D";
    "DATE:"&Tday$&" JULIAN DAY:",Julday,
    "LATITUDE:",Lat,"SUBSIDENCE:",Wsl,"SURFACE TEMP:",
    Sea
450 PRINT USING "/,K,/";"FORECAST WINDS FOR THE PERIOD [
    KNOTS]"
455 FOR Win=1 TO Wn
460 PRINT USING "ZZ,2A,2X,3D.D";Windin(win,1)/2 MOD 24,
    "00",Windin(win,2)*1.94
465 NEXT Win
470 IF Hd$="Y" THEN RETURN
475 DISP "PRESS CONT WHEN READY"
480 PAUSE
485 RETURN
490 Jullat: PRINT USING "@,K,/,K,3D";"FOR DATA SET: "&Loc$&
    " "&Time$,"CURRENT JULIAN DAY: ",Julday
495 INPUT "ENTER NEW JULIAN DAY(1 TO 366), PRESS CONT
    ",Julday
500 PRINT USING "@,K,M2D.4D";"CURRENT LATITUDE IS :";Lat
505 INPUT "ENTER LATITUDE(DEG -90 TO 90), PRESS CONT
    ",Lat
510 RETURN
515 Enter_winds: PRINTER IS 16!KNOTS = METERS *1.94 |
    1.94= ft * Nm *3600sec
520 MAT Windin=ZER ! SECOND |
    .3048m 6076.1ft Hr
525 ON ERROR GOTO 530
530 PRINT USING "@,K, 4X ,K";Loc$,Time$
535 INPUT "ENTER THE BEGINNING TIME ( TO NEAREST HOUR
    e.g. 0600)",In11$
540 IF (LEN(In11$)<>4) OR (VAL(In11$[1;2])>24) THEN 530
545 IF In11$[1;2]="00" THEN In11$[1;2]="24"
550 REDIM G(VAL(In11$[1;2])*2-1:VAL(In11$[1;2])*2+61,7)

```





```

555 OFF ERROR
560 Wn=1
565 Windin(1,1)=Nr11=VAL(In11$(1;2))*2 ! PUT PERIOD IN
    WIND HOLDING ARRAY
570 QS="Y"
575 Wind_begin1=wind ! USE THE VALUE
    FROM IREPS
580 PRINT USING "@,KX,3D.D,2XK";"WIND FROM IREPS IS ";
    Wind*1.94,"KNOTS"
585 INPUT "IS THIS WIND OKAY? PRESS CONT TO USE THIS
    WIND (Y/N)",QS
590 IF QS(1;1)="Y" THEN 610
595 DISP "ENTER BEGINNING WIND SPEED [KNOTS] at time ";
    In11$;
600 INPUT Wind_begin1
605 Wind_begin1=Wind_begin1/1.94 !CHANGE INTO
    METERS PER SECOND
610 PRINT USING "@,K,4A,K,3D.D,6A";"AT BEGINNING TIME: ";
    In11$(1;2)&"00";" THE WIND SPEED IS ";Wind_begin1*
    1.94;" KNOTS"
615 PRINT USING "2/,K,2(/,K)";"Enter the hour and minutes
    of each prediction, then the wind.", "Separate time
    from wind by a comma", "DISPLAYED winds in KNOTS"
620 PRINT USING "/,K,2Z,16A,/,K";"The last period is 30
    hours after the beginning (i.e. ",(Nr11/2+30) MOD
    24,"00 the next day)", "PERIOD TIME WIND"
625 PRINT USING "X2D,5X,4A,5X,2D.D";1,In11$(1;4),
    Wind_begin1*1.94
630 G(Nr11+50,3)=Windin(1,2)=MAX(Wind_begin1,.0001)
635 QS="Y"
640 FOR win=2 TO 10 ! MAX OF 10 WIND INPUTS....FIRST
    ONE FROM ABOVE
645 One_wind: LINPUT "hhmm,ww FROM THE FORECAST,
    ENTER TIME,WIND(KNOTS) [END when done]",In12$
650 IF (In12$(1;2)="99") OR (UPC$(In12$(1;1))="E") THEN
    Print_wind
655 IF (LEN(In12$)<5) OR (In12$="") THEN 645
660 IF NOT (In12$(5;1)="," ) OR (VAL(In12$(1;2))>24) OR (
    In12$(6;1)="") THEN 645
665 PRINT USING "X2D,5X,4A,5X,K";win,In12$(1;4),In12$(6)
670 Windin(win,1)=VAL(In12$(1;2))*2 ! TIMES 2 TO GET
    # OF PERIOD
675 G(Nr11+60,3)=windin(win,2)=MAX(VAL(In12$(6))/1.94,
    .0001)
680 IF UPC$(QS(1;1))="N" THEN RETURN
685 Wn=win ! COUNT THE TOTAL
    WINDS ENTERED
690 NEXT win
695 Print_wind: QS="Y" ! HERE TO PUT WIND IN 'G' ARRAY
700 PRINT PAGE,"WINDS THROUGH FORECAST PERIOD"
705 FOR win=1 TO Wn

```





```

710 PRINT USING "5X,2D,2X,ZZ,2A,2X,3D.D";Win,windin(win,1)/
    2 MOD 24,"00",windin(win,2)*1.94
715 NEXT Win
720 Q$="Y"
725 INPUT "DO THESE WINDS LOOK OKAY (Y/N)?",Q$
730 IF UPC$(Q$(1,1))="Y" THEN 745
735 IF UPC$(Q$(1,1))="N" THEN Fixwind
740 GOTO Print_wind
745 G(Nr11-1,3)=G(Nr11,3)=windin(1,2)
750 winl=0
755 Idayl=Nr11
760 FOR Win=2 TO Wn
765 IF windin(Win,1)<Idayl THEN winl=winl+48
770 G(MIN(windin(Win,1)+winl,Nr11+61),3)=windin(Win,2)
    !TO PREVENT TIME BEYOND
775 Idayl=windin(Win,1)
780 G(Nr11+60,3)=windin(Win,2) ! AUTOMATIC PUT THE LAST
    WIND INTO END PERIOD
785 NEXT Win
790 RETURN
795 Fixwind: INPUT "ENTER PERIOD NUMBER TO CHANGE",Win
800 IF Win>Wn THEN Fixwind
805 GOSUB One_wind
810 GOTO Print_wind
815 Subsidence: ! COME HERE NORMALLY OR FOR RETRY WITH
    DIFFERENT SUBSIDENCE
820 FIXED 4
825 DISP "ENTER SUBSIDENCE (m/sec) [Prior value=";wsl;"],
    or CONT to use same value";CHR$(7);
830 INPUT wsl
835 RETURN
840 Sea_temp: PRINT "PRESENT VALUE OF SEA SURFACE
    TEMPERATRURE IS ";Sea
845 INPUT "ENTER THE SEA SURFACE TEMP IN 'C or just
    CONT for same value",Sea
850 Tsfc=Sea+273.16
855 RETURN
860 Assig_error: IF ERRN=80 THEN No_data
865 DISP "ERROR #";ERRN;" in line ";ERRL;" PRESS
    CONT when ready",CHR$(7)
870 PAUSE
875 GOTO Start
880 No_data: PRINT PAGE,"DATA FILE NOT AVAILABLE IN LEFT
    TAPE DRIVE.",LIN(2),"EITHER NO TAPE or NOT A DATA
    TAPE.",LIN(2)
885 PRINT "INSERT OR MAKE OTHER CHOICE",LIN(2),"PRESS
    CONT TO TRY AGAIN WITH DATA TAPE IN LEFT SIDE
    TAPE DRIVE"
890 BEEP
895 PAUSE
900 Ireps_data: ! TO DISPLAY THE FILE NAMES OF DATA ON

```



```

      IREPS DATA TAPE
905  ON ERROR GOTO Assig_error
910  ASSIGN #5 TO "ENVIR"&Mass$,Ier
915  IF Ier THEN No_data
920  ASSIGN #6 TO "SEQNCE"&Mass$,Ier
925  IF Ier THEN No_data
930  READ #6;Envsq(*),Syssq(*),Lossq(*)
935  ON END #5 GOTO All_out
940    FOR I=1 TO 16
945      READ #5,I;Envnam$(I)
950    NEXT I
955  GOTO All_full
960 All_out:  FOR J=I TO 16    ! I HAS BEEN INCREMENTED 1
      ABOVE LAST READ I
965  Envsq(J)=0
970  NEXT J
975 All_full:  RETURN    ! ARRAY FILLED WITH NAMES and
      REMAINDER WITH 0's

980 Disp_data:  PRINTER IS 16 ! TO PUT THE DATA SETS UP FOR
      CHOICE
985  PRINT USING "@,K,5X,K,2/,5X,2D,2X,K";CHR$(7),
      "EXISTING ENVIRONMENTAL DATA SETS ON IREPS TAPE:",
      0,"NEW or RETURN TO MENU SELECTION"
990  FOR I=1 TO 16
995  Rec=Envsq(I)
1000  IF NOT Rec THEN Pick_data
1005  PRINT USING "5X,DD,2X,K";I,Envnam$(Rec)[1,23]
1010  NEXT I
1015  I=17
1020 Pick_data:  Nrec=I-1
1025  OFF ERROR
1030  IF Nrec<=0 THEN Menu
1035  INPUT "ENTER THE NUMBER OF THE DATA SET DESIRED",
      Dummy
1040  IF Dummy=0 THEN Menu
1045  IF NOT ((Dummy>=1) AND (Dummy<=Nrec)) THEN Disp_data
1050  Rec=Dummy
1055  DISP "PROGRAM IS WORKING RECORD NUMBER ",Rec,";",
      TRIM$(Envnam$(Envsq(Rec))[1,23])," IS BEING READ"
1060  READ #5,Envsq(Rec);Name$,Loc$,Time$,Type$,Hight$,
      Evap$,Wmo$(*),Wmoht$
1065  READ #5;Presur(*),Temper(*),Relhum(*),Height(*),
      Munits(*),Nunits(*)
1070  READ #5;Wind,Sea,Air,Relhm,Htzero,Przero,Nmax,Delta,
      Change
1075  FOR I=1 TO Nmax-1
1080  IF (Presur(I)=0) OR (Height(Nmax-I+1)>10000) OR (I=21)
      THEN GOTO 1110
1085  Spec_hum(I)=FNQvalue(Temper(I),Relhum(I))

```



```

1090      Pct_temp(I)=Temper(I)+.0098*Height(Nmax-I)
1095      Zsnd(I)=Height(Nmax-I)*1
1100      Digit_top=I
1105 NEXT I
1110      Press=Przero
1115      IF Press=0 THEN Press=1012 !DEFAULT TO STANDARD IF
      NO OTHER VALUE
1120      MAT G=ZER
1125      Flag_rev=0 ! TO FLAG A NEW DATA SET
1130      Flag_data=1 ! TO FLAG A DATA SET CHOSEN
1135      RETURN ! GET THE WINDS THEN DO VERTICAL
      STRUCTURE

1140 Plt_struct: !
1145 PLOTTER IS 13,"GRAPHICS"
1150 GRAPHICS ! *****LABEL
      VERTICAL PLOT*****
1155 PEN 1
1160 LINE TYPE 1
1165 SCALE -3,30,-200,2400
1170 CLIP 0,30,0,2400
1175 AXES 1,500,0,0,5,2
1180 UNCLIP
1185 LORG 2
1190 MOVE -3,-65
1195 LABEL USING "K";"SPEC. HUM. Q"
1200 MOVE -3,-130
1205 LABEL USING "K";"POT. TEMP. °C"
1210 LORG 8
1215 MOVE 30,2285 ! *****DRAW WIND ON
      PLOT*****
1220 LABEL USING "8AX";"FORECAST"
1225 MOVE 30,2225
1230 LABEL USING "K";"TIME WIND"
1235 FOR L=1 TO Wn
1240 MOVE 30,2200-L*80
1245 BEEP
1250 LABEL USING "ZZ,2A,2X,3D.D";Windin(L,1)/2 MOD 24,"00",
      Windin(L,2)*1.94
1255 NEXT L
1260 LORG 5
1265 FOR L1=1 TO 2
1270 FOR L=5 TO 25 STEP 5
1275 MOVE L,-65*L1
1280 LABEL USING "M3D";L*L1-(L1-1)*10
1285 NEXT L
1290 NEXT L1
1295 FOR L=500 TO 2000 STEP 500 ! *****LABEL SIDE
      NUMBERS*****

```



```

1300 MOVE -1,L
1305 LABEL USING "4D";L
1310 NEXT L
1315 DEG
1320 LDIR 90
1325 LORG 2
1330 MOVE -2.5,0
1335 LABEL USING "K";LocS&" "&TimeS&" "&"HEIGHT (meters)
      "&Tday$
1340 LDIR -80
1345 MOVE 3,2400
1350 LABEL USING "XK";"SPECIFIC HUMIDITY Q"
1355 LORG 8
1360 LDIR 80
1365 MOVE 22,2400
1370 LABEL USING "K";"POTENTIAL TEMP O"
1375 MOVE 22,2400
1380 LABEL USING "A";"-"
1385 LDIR 0
1390 LORG 5
1395 MOVE 25,500 !*****LABEL
      LEGEND*****
1400 LABEL USING "15A";"  $\sqrt{Q}$  |Theta_/"
1405 LORG 8
1410 MOVE 30,750
1415 LABEL USING "10A,2X,MZ.4D";"Subsidence",wsl
1420 MOVE 25,600
1425 LABEL USING "18A";"MIXED LAYER HEIGHT"
1430 FOR L=1 TO 3
1435 MOVE 25,500-L*100
1440 LABEL USING "14A,7X";Stick$(L)
1445 NEXT L
1450 SCALE -16,50,-200,2400
1455 MOVE Pot_temp(1),Height(Nmax) !*****DRAW THETA *
      *****
1460 FOR L=2 TO MIN(Nmax-1,Digit_top)
1465 DRAW Pot_temp(L),Height(Nmax-L)
1470 NEXT L
1475 Zi=Zi3
1480 POINTER Pot_temp(2),Height(Nmax-3),1 ! FULL SCREEN
      CURSOR
1485 BEEP !*****GET THETA***
      *****
1490 DIGITIZE Mixtemp,Zi
1495 MOVE 40,600
1500 LORG 2
1505 LABEL USING "X4D,2A";Zi;"m."
1510 MOVE 40,200
1515 LABEL USING "XM2D.D";Mixtemp
1520 BEEP
1525 POINTER Mixtemp+5,Zi,2

```





```

1530 DIGITIZE Top_inv_temp,Mmm
1535 MOVE 40,300
1540 LABEL USING "X2D.D";Top_inv_temp-Mixtemp
1545 POINTER Top_inv_temp+10,2350,2
1550 BEEP
1555 DIGITIZE Top_temp,Top_temp_alt
1560 MOVE 40,400
1565 LABEL USING "XZ.4D";(Top_temp-Top_inv_temp)/(
      Top_temp_alt-Zi) !

1570 LINE TYPE 3          !*****DRAW STICK THETA*****
      **
1575 MOVE Mixtemp,0
1580 DRAW Mixtemp,Zi
1585 DRAW Top_inv_temp,Zi
1590 DRAW Top_temp,Top_temp_alt
1595 LINE TYPE 1
1600 LORG 8 !WRITE UNDER 'Q' SIDE
1605 SCALE -3,30,-200,2400
1610 BEEP
1615 LINE TYPE 8
1620 MOVE Spec_hum(1),Height(Nmax) !*****DRAW Q ****
      *****
1625 FOR L=2 TO MIN(Nmax-1,Digit_top)
1630 DRAW Spec_hum(L),Height(Nmax-L)
1635 NEXT L
1640 LINE TYPE 1
1645 POINTER Spec_hum(2),Zi,1
1650 DIGITIZE Mixq,Mmm ! USING THIS TERM SO SCALE STAYS
      THE SAME
1655 MOVE 25,200
1660 LABEL USING "M2D.2DX";Mixq
1665 POINTER Mixq/2,Zi,2
1670 BEEP
1675 DIGITIZE Top_inv_q,Mmm ! USE FOR SAME SCALE FACTOR
      GRAPHICS
1680 MOVE 25,300
1685 LABEL USING "M2D.2DX";Top_inv_q-Mixq
1690 POINTER Top_inv_q/2,2350,2
1695 BEEP
1700 DIGITIZE Top_q,Top_q_alt
1705 MOVE 25,400
1710 LABEL USING "M.4DX";(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1715 Zi3=Zi
1720 LINE TYPE 4          !*****DRAW STICK Q *****
      ***
1725 MOVE Mixq,0
1730 DRAW Mixq,Zi
1735 DRAW Top_inv_q,Zi

```



```

1740   DRAW Top_q,Top_q_alt
1745   LINE TYPE 1
1750   SCALE -16,50,-200,2400
1755   MOVE 40,100
1760   LOG 5 !***** FOR DECISION OF A GOOD FIT OR
      NOT*****
1765   LABEL USING "17A";" OKAY <-|-> AGAIN"
1770   POINTER 40,100,2
1775   BEEP
1780   DIGITIZE D,Mmm
1785   IF D=40 THEN 1770
1790   IF D>40 THEN Plt_struct
1795   PRINTER IS 16
1800   PRINT PAGE
1805   MOVE 40,100
1810   DISP "CLEARING PICTURE"
1815   EXIT GRAPHICS
1820   PEN -1
1825   LABEL USING "17A";" OKAY <-|-> AGAIN"
1830   GOSUB Hard_output
1835   IF Hd$="N" THEN 1885
1840   PRINTER IS 0
1845   PRINT USING " 1X,K,2(6X,K),/";"ENVIRON. DATA LIST,
      FROM MIXED2",Loc$,Time$
1850   PRINT USING "3(10A,X4D.D,9X18A,M3D.D,/);" "WIND",Wind,
      "AIR TEMP",Air,"SEA TEMP",Sea,"REL HUM",Relhm,"SFC
      PRESS",Przero,"IREPS EVAP DUCT HT",Delta
1855   PRINT "LEVEL PRESS TEMP RH % METERS M UNITS
      POTENT TEMP SPEC HUM"
1860   FOR I=1 TO MIN(18,Digit_top)
1865   PRINT USING "3D,3X,4D.D,2X,M2D.D,X,3D.D,X,6D.D,4X,4D,2(
      6X,M3D.D)";I,Presur(I),Temper(I),Relhum(I),Height(
      Nmax-I),Munits(Nmax-I),Pot_temp(I),Spec_hum(I)
1870   NEXT I
1875   DUMP GRAPHICS
1880   PRINT USING "@"
1885   PRINTER IS 16
1890   EXIT GRAPHICS
1895   RETURN
1900   Run: T10=Mixtemp !*****PREP DATA FOR RUN WITH
      IREPS*****
1905   Zi=Zi3
1910   Qp=Mixq
1915   Dqp=Top_inv_q-Mixq
1920   Dqdzu=(Top_q-Top_inv_q)/(Top_q_alt-Zi)
1925   Dth=Top_inv_temp-Mixtemp
1930   Dtdzu=(Top_temp-Top_inv_temp)/(Top_temp_alt-Zi)
1935   Ws=ws1
1940   Frame_loc$=Loc$
1945   Frame_date$=Time$
1950   EXIT GRAPHICS

```



```

1955     CALL Sky2(Zi,Nmax*1,Pot_temp(*),Zsnd(*),Spec_hum(*),
           Tsky,Ftop)
1960     Mhr=60                ! TO SET MHR= NUMBER OF HALF HOUR
           PERIODS
1965     OFF ERROR
1970     PRINT PAGE,TAB(9),"THIS IS 'MIXED2', MODELING THE
           CHANGE IN THE MIXED LAYER"
1975     PRINT TAB(10),"ABOVE THE OCEAN SURFACE. Today is "&
           Tday$
1980     Numhr=Nr11+Mhr
1985     PRINTER IS 16
1990     PRINT USING "/",15X,K,/,20X,4Z,2XK,/,19X,4D,K,/" ; "DATA
           PARAMETERS CHOSEN",Nr11/2 MOD 24*100,"BEGINNING
           TIME",Zi,"m  CAPPING INVERSION HEIGHT"
1995     Vdt=0
2000     ! INPUT "ENTER A VALUE FOR 'Vdte' ('C/12hr) , or PRESS
           CONT FOR DEFAULT TO 0 ?",Vdt
2005     Vdte=Vdt/24
2010     ! PRINT "THE VALUE FOR 'Vdte' IS ";Vdt;" 'C/12hr   or ";
           Vdte;" 'C per TIME STEP"
2015     Th=Tl0+273.16
2020     J=Nr11-1
2025     G(Nr11-1,1)=Zi
2030     GOSUB Bulk
2035     Nr1=Nr11
2040     I=Nr1                ! FIND FIRST INPUT DATA LINE
2045     I=I+1                ! INCREMENT TO NEXT LINE
2050     IF G(I,3)=0 THEN 2045! IF NO DATA, INCREMENT
2055     Nd=I-Nr1             ! FIGURE TIME SPREAD
2060     X5=(G(I,3)-G(Nr1,3))/Nd !U10
2065     FOR J=1 TO Nd-1      ! STEP THROUGH EMPTY POINTS
2070         G(J+Nr1,3)=G(Nr1,3)+X5*J
2075     NEXT J                ! DQDZU= Specific hum
           gradient above inv.
2080     Nr1=I                ! DTH= Potential
           temperature jump
2085     IF I<Numhr THEN 2045 ! DTDZU= Temp
           gradient above inversion
2090     T=Th-.0098*Zi*.5-273.16 ! DQW= Specific
           humidity jump
2095     Lcp=(596.73-.601*T)/.24 ! TH= Well mixed
           potential temperature
2100     Tt=T-.0098*Zi*.5+273.16 ! Qp= Well mixed
           specific humidity
2105     Te=Th*(1+Lcp/Tt*Qp/1000) ! ZI= Inversion height
2110     Dte=Dth+Th/Tt*Lcp*Dqp/1000 ! DELTIM=Time step
           between solutions
2115     Dtedzu=Dtdzu+Th/Tt*Lcp*Dqdzu/1000
2120     Dqw=Dqp/1000
2125     Qw=Qp/1000
2130     Aws=Ws/Zi            ! AVERAGE Ws THRU THE MIXED

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      LAYER
2135      Zws=Zi                      ! REMEMBER HEIGHT OF
      BEGINNING ws
2140 PLOTTER IS 13,"GRAPHICS"
2145 SCALE Nr11-20,Nr11+80,-100,2000
2150 CLIP Nr11,Nr11+61,0,1200
2155 AXES 4,200,Nr11,0,3,5
2160 FRAME
2165 GRAPHICS !

2170      Run$="* "
2175 Loop:  FOR J=Nr11 TO Nr11+Mhr
2180      Zil=Zi                      ! HOLD ONTO PREVIOUS HEIGHT
2185      PLOT J,Zi                  ! FOR THE QUICK PLOT
2190      Tl0=Th-273.16             ! Tl0 CARRIED BACK FROM 'Bulk' AS Th
2195      Ql0=Qp                    ! NEW VALUE OF Qp
2200      FIXED 2
2205      Dtedzu=Dtdzu+Th/Tt*Lcp*Dqdz/1000
2210      IF J>Nr11+56 THEN Run$="!"
2215      DISP "PERIOD BEGIN:";TAB(14+(J-Nr11)/2);Run$;TAB(
          45);":END      Layer at";G(J-1,1)
2220      O2=Dqdz/1000              ! TO CHANGE G/KG TO G/
          G
2225      Timesec=J*1800
2230      CALL Zenith(Timesec,Julday,Lat,Theta)
2235      CALL M2(Tl0,Ql0,Zlcl,Zi,Ustar,Tstar,Qstar,Tstv,ws,Delr,
          O2,Dte,Dqw,Dhdt,Ddtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,
          Dtedzu,Tsfc,Theta,Tsky)
2240      G(J,2)=Zlcl
2245      G(J,1)=Zi=Zi+Dhdt*Deltim
2250      Qw=Qw+Dqwdt*Deltim          ! GRAMS PER GRAM
2255      G(J,4)=Ql0=Qp=Qw*1000      ! GRAMS PER KILOGRAM
2260      Te=Te+Dtedt*Deltim          ! EQUIVALENT POTENTIAL
          TEMP
2265      Dqw=Dqw+Ddqwdt*Deltim      ! GRAMS PER GRAM
2270      G(J,6)=Dqp=Dqw*1000         ! GRAMS PER KILOGRAM
2275      Dte=Dte+Ddtedt*Deltim+Vdte ! ADDING THERMAL WIND
2280      ws=Aws*Zi                  ! RESETTING LAYER
          SUBSIDENCE
2285      Zws=Zws+Aws*Zws*Deltim
2290      Tt=Tt-.0098*(Zi-Zil)        ! Tt IN KELVIN
2295      T=Tt+.0098*Zi*.5-273.2
2300      Lcp=(596.73-.601*T)/.24
2305      G(J,5)=Th=Te/(1+Lcp*Qw/Tt)  ! Th in KELVIN
2310      G(J,7)=Dth=Dte-Th/Tt*Lcp*Dqw
2315      ! G(J,2)=MIN(100,FNRelhum(Qp,Th)) ! FIGURED AT 10
          METER LEVEL

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2320      GOSUB Bulk ! COMPUTE STAR VALUES FOR NEXT TIME
          PERIOD

2325      NEXT J
2330      EXIT GRAPHICS
2335      GOTO Menu !

2340 Bulk: ! TO COMPUTE THE NEXT SET OF VALUES FOR U*,T*,Q*,
          T*v
2345      U10=MAX(.2,G(J,3)) ! WIND CHANGES THROUGH THE PERIOD
2350      IF U10>=2.2 THEN Cdn=.789*U10^.259/1000 ! FIGURE
          DRAG FROM WIND CURVE FIT
2355      IF U10<2.2 THEN Cdn=U10^(-.15)*1.08/1000 ![ DAB
          SEP 80]
2360      RAD
2365      Tdelta=Th-Tsfc ! DIFFERNE IN TEMPERATURE AND Q-
          value
2370      Qdelta=Qp-FNQvalue(Sea,98) ! FROM 10meters TO THE
          SURFACE
2375      Zo=Z*EXP(-Kkk/SQR(Cdn))
2380      Ctn_sqrt=Alpha_t*Kkk/LOG(Z/Zot)
2385      S1=S=So=Kkk*9.8*Z/Th*(Ctn_sqrt/Cdn)*(Tdelta+.00061*
          Th*Qdelta)/U10^2
2390      IF So<0 THEN 2450
2395      IF So<2 THEN GOTO 2420
2400          S=10
2405          Psi1=-47
2410          Psi2=-64
2415          GOTO Stars
2420          Psi1=-S*4.7
2425          Psi2=-S*6.4
2430          S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
          Kkk-Ctn_sqrt*Psi2))
2435      IF ABS(S-S1)<.001 THEN Stars
2440          S1=S
2445      GOTO 2420
2450          X1=(1-15*S)^(.25)
2455          X2=(1-9*S)^(.5)
2460          Psi2=2*LOG((1+X2)/2)
2465          Psi1=2*LOG((1+X1)/2)+LOG((1+X1^2)/2)-2*ATN(X1)+
          PI/2
2470          S=So*Alpha_t/Kkk*((Kkk-SQR(Cdn)*Psi1)^2/(Alpha_t*
          Kkk-Ctn_sqrt*Psi2))
2475      IF ABS(S-S1)<.001 THEN Stars
2480          S1=S
2485      GOTO 2450
2490 Stars: Mult=Alpha_t*Kkk/(LOG(Z/Zot)-Psi2)
2495          Ustar=Kkk*U10/(LOG(Z/Zo)-Psi1)
2500          Tstar=Tdelta*Mult
2505          Qstar=Qdelta*Mult

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2510      Tstv=Tstar+.61*Qstar*Th/1000
2515  RETURN ! VALUES BACK FOR BEGINNING AND FOR DURING
      RUN

2520 Picture: EXIT GRAPHICS
2525  IF NOT Flag_data THEN Menu
2530      PRINTER IS 16
2535      OFF ERROR
2540      PRINT USING "a,k,2/,3(10X,k,2/);"TYPE OF PLOT:","1
          PLOT THE 'BIG PICTURE',"2 PLOT OF 'Q', 'THETA'
          AND JUMPS","3 LIST OF THE PLOTTED VALUES"
2545      PRINT "          4 RETURN TO DIRECTION MENU"
2550      ON ERROR GOTO Picture
2555      INPUT "ENTER MODE of output?",Vss
2560      PRINT PAGE,"PRESS CONT when picture is done",LIN(
          2)," [ k3 TO DISPLAY GRAPHICS]"
2565      IF Vss=1 THEN CALL Frame(G(*),Nr11,Tday$,Dqdz,
          Dtdzu,Press,Frame loc$,Frame date$,Mhr)
2570      ON Vss GOTO Picture,Mix_plot,Gval,Menu
2575 ! ON Vss GOTO Picture,Picture,Gval,Menu
2580      GOTO Picture
2585 Hard_output: Hd$="N"
2590      INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
2595      Hd$=UPC$(Hd$[1,1])
2600      IF (Hd$="Y") OR (Hd$="N") THEN RETURN
2605      GOTO Hard_output !

2610 Gval:! PRINT OUT THE VALUES FOR THE ENTIRE PERIOD
2615  GOSUB Hard_output
2620  OFF ERROR
2625  IF Hd$="Y" THEN PRINTER IS 0
2630  LS="This is a list of plotted values. "&Loc$&" "&
      Time$&" "&Tday$
2635  PRINT LS[1;78],LIN(1)
2640  PRINT "HOUR   Zi   Zlcl RelHum WIND   Th   Qp
          Thv   Dth   Dthv   Dqp"
2645  FOR G1=Nr11 TO Nr11+Mhr
2650      G2=INT(G1 MOD 48/2)*100+FRACT(G1 MOD 48/2)*60
2655      G3=G(G1,5)*(1+.00061*G(G1,4))! Thv
2660      G4=G(G1,7)+.00061*G(G1,5)*G(G1,6)! Dthv
2665      G5=FNRelhum((G(G1,4)),(G(G1,5)))
2670      PRINT USING "4Z2X,2(4DX),2(M3D.DX),6(3D.D2X)";G2,G(
          G1,1),G(G1,2),G5,G(G1,3),G(G1,5)-273.16,G(G1,4),
          G3-273.16,G(G1,7),G4,G(G1,6)
2675  NEXT G1
2680  PRINT "HOUR   Zi   Zlcl RelHum WIND   Th   Qp
          Thv   Dth   Dthv   Dqp"
2685  DISP "PAUSING FOR 2 SECONDS THEN RETURNING TO THE
          START"

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2690 IF Hd$="N" THEN WAIT 2000
2695 ! WHEN YOU ARE READY, JUST PRESS CONT
2700 PRINT PAGE
2705 GOTO Picture!

2710 Mix_plot: BEGIN PLOT OF Qp,Dqp,Th,Dth,RH
2715 OFF ERROR
2720 PLOTTER IS 13,"GRAPHICS"
2725 GRAPHICS
2730 FRAME
2735 SCALE Nr11-5,Nr11+60,-8,8
2740 CLIP Nr11,Nr11+60,-8,8
2745 AXES 2,1,Nr11,0,3,1
2750 LORG 2
2755 MOVE Nr11,7.5
2760 LABEL USING "K";" POTENTIAL TEMPERATURE [°C]"
2765 MOVE Nr11,7
2770 LABEL USING "K";" POT TEMP jump - - -"
2775 MOVE Nr11,-.5
2780 LABEL USING "K";" SPECIFIC HUMIDITY [g/kg]"
2785 MOVE Nr11,-1
2790 LABEL USING "K";" SPEC HUM jump - - -"
2795 FOR K=0 TO 2 STEP 2
2800 LORG 8
2805 SCALE Nr11-5,Nr11+60,INT(G(Nr11,4+K))-4,INT(G(Nr11,
    4+K))+12
2810 FOR I=0 TO 1
2815 P=-2
2820 LINE TYPE 1
2825 FOR L=INT(G(Nr11,4+K+I))-3-273.16*((K=0) AND (I=1)))
    TO INT(G(Nr11,4+K+I)+3-273.16*((K=0) AND (I=1)))
2830 MOVE Nr11+K*30,L
2835 LABEL USING "MDDX";L
2840 NEXT L
2845 LINE TYPE 1+3*(K=2)
2850 FOR J=Nr11 TO Nr11+60
2855 PLOT J,G(J,4+I+K)-((I=1) AND (K=0))*273.16,P
2860 P=-1
2865 NEXT J
2870 SCALE Nr11-5,Nr11+60,INT(G(Nr11,5+K)-12-273.16*(K=0)
    ),INT(G(Nr11,5+K)+4-273.16*(K=0))
2875 NEXT I
2880 LINE TYPE 4
2885 NEXT K
2890 GOSUB Hard_output
2895 IF Hd$="Y" THEN PRINTER IS 0
2900 PRINT USING "K";"TEMPERATURE and HUMIDITY for "&Loc$&
    " "&Time$
2905 IF Hd$="Y" THEN DUMP GRAPHICS
2910 GCLEAR

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2915 SCALE Nr11-5,Nr11+60,-20,120
2920 LINE TYPE 1
2925 CLIP Nr11-5,Nr11+60,40,100
2930 FRAME
2935 AXES 2,10,Nr11,40,3,2
2940 MOVE Nr11,FNRelhum((G(Nr11,4)),(G(Nr11,5)))
2945 FOR I=Nr11+1 TO Nr11+60
2950 DRAW I,FNRelhum((G(I,4)),(G(I,5)))
2955 NEXT I
2960 LORG 2
2965 MOVE Nr11,105
2970 LABEL USING "K";" RELATIVE HUMIDITY at 10 meter
    level"
2975 LORG 7
2980 MOVE Nr11,80
2985 LABEL USING "3AX";"80%"
2990 MOVE Nr11,60
2995 LABEL USING "3AX";"60%"
3000 FOR Cc=Nr11 TO Nr11+60 STEP 12
3005 MOVE Cc,110
3010 LABEL USING "ZZ,ZZ";INT(Cc/2) MOD 24,FRACT(Cc/2)*60
3015 NEXT Cc
3020 IF Hd$="Y" THEN DUMP GRAPHICS 40,115
3025 BEEP
3030 IF Hd$="N" THEN PAUSE
3035 EXIT GRAPHICS
3040 IF Hd$="N" THEN Picture
3045 PRINTER IS 0
3050 PRINT USING "2(/,9XK)";"30-HOUR PREDICTION OF
    POTENTIAL TEMPERATURE AND HUMIDITY","The well-
    mixed value scale is along the left, the 'jump'
    value"
3055 PRINT USING "8XK,@";"scale is along the right. The
    third frame is Relative Humidity."
3060 GOTO Picture!

3065 Bye: PRINT PAGE,"THIS PROGRAM IS ENDING AND REWINDING
    THE TAPE"
3070 PRINT LIN(1),"REMOVE TAPE BY PRESSING THE EJECT BAR"
3075 ON ERROR GOTO 3085
3080 REWIND ":T15"
3085 ON ERROR GOTO 3095
3090 REWIND ":T14"
3095 PRINT LIN(6),TAB(36),"Good bye"
3100 BEEP
3105 OFF ERROR
3110 En: END!

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3115 SUB M2(Tl0,Ql0,Zlcl,Zi,Ust,Tst,Qst,Tstv,Ws,Delr,Dqdzu,
      Dte,Dqw,Dhdt,Dtedt,Ddqwdt,Dtedt,Dqwdt,Wtv,Dtedzu,
      Tsfc,Theta,Tsky)
3120   Tt=Tl0+273.2-.0098*Zi/2
3125   Thet=(Tt+Zi*.0098)/Tt
3130   Cl=(596.73-.601*(Tt-273.2))/(.24*Tt)  ! Cl=L/(Cp*T)
3135   Wt=-Tst*Ust
3140   Wtv=-Tstv*Ust
3145   Wq=-Qst*Ust/1000
3150   Wte=Wt+Thet*Cl*Tt*Wq
3155   Te=Tl0+2.43*Ql0
3160 CALL Parcel0(Te,Ql0,Zi,Rh,Thr,Qv,Ql,Zlcl)
3165   Qs=Qv/1000*Rh/100
3170   Qliq=Ql/1000
3175   ! WAIT 1000
3180 CALL We2(Zi,Zlcl,Dte,Dqw,Qs,Thr,Qliq,Tl0,Tsfc,Ust,Tst,
      Qst,Tstv,We2,Delr,Tsky)  ! NEED TO CALL PARCEL
      FIRST
3185 CALL Shrtwv(Theta,Ql,Zlcl,Zi,Ql0,Dtemp)
3190   We=We2
3195   Dhdt=We+Ws  ! Rate of change of mixed layer deptn,
      Ws is subsidence
3200   Dtedt=Dtedzu*We+(-We*Dte-Wte+Thet*Delr)/Zi-Dtemp
3205   Ddqwdt=Dqdzu*We+(-We*Dqw-Wq)/Zi
3210   Dtedt=(Wte-Thet*Delr+We*Dte)/Zi+Dtemp
3215   Dqwdt=(Wq+We*Dqw)/Zi
3220 SUBEND  ! END OF 'M2' SUBPROGRAM

3225 DEF FNQvalue(SHORT Tx,R)  !FIGURE THE 'Q' VALUE
      GIVEN:
3230   Qvb=.053542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-3))*R
3235   RETURN Qvb !TAKE THE Q value BACK
3240   FNEND!

3245 Frame:SUB Frame(SHORT G(*),REAL Nr11,Tday$,Dqdzu,Dtdzu,
      Press,Frame_loc$,Frame_date$,Mhr)
3250   OPTION BASE 1
3255   DIM Zg(4)
3260   PLOTTER IS 13,"GRAPHICS"
3265   GRAPHICS
3270   SCALE Nr11-6,Nr11+60,-200,2400
3275   CLIP Nr11,Nr11+60,0,2400
3280   AXES 2,100,Nr11,0,6,2,3
3285   MOVE Nr11+26,-110
3290   LONG 5
3295   DEG
3300 LABEL USING "K";"Atmospheric Mixed Layer Movement 30
      Hours "&Tday$

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3305 MOVE Nr11+26,-170
3310 LABEL USING "K";Frame_loc$&" "&Frame_date$&" LT D.
      BROWER NPS"
3315 LDIR 90
3320 MOVE Nr11-4.5,600
3325 LABEL USING "K";"Mixed Layer(meters)"
3330 MOVE Nr11-4.5,1800
3335 LABEL USING "K";"DUCT HEIGHT (meters)"
3340 CSIZE 2.7,.6
3345 LDIR 0
3350 MOVE Nr11+30,1050
3355 LABEL USING "K";"Vertical Profile 'M-value' (every
      SIX hours)"
3360 FOR Cc=Nr11 TO Nr11+Mhr STEP 12
3365 MOVE Cc,-30 !Print out time at bottom
3370 Bb=INT(Cc/2)
3375 Bbb=FRAC(T(Cc/2)*60
3380 Bb=Bb MOD 24
3385 LABEL USING "ZZ,ZZ";Bb,Bbb
3390 Bb=(Bb+3) MOD 24
3395 MOVE Cc+6,2370 ! PRINT OUT TIME AT TOP
3400 LABEL USING "ZZ,ZZ";Bb,Bbb
3405 NEXT Cc
3410 FOR Cv=1 TO 5 ! Label side
3415 MOVE Nr11-2,Cv*200
3420 LABEL USING "4D";Cv*200
3425 NEXT Cv
3430 MOVE Nr11,G(Nr11,1)
3435 GRAPHICS
3440 FOR V=Nr11+1 TO Nr11+Mhr! Draw out the max 'M' neight
      at the inversion
3445 DRAW V,G(V,1)
3450 NEXT V
3455 LINE TYPE 4
3460 MOVE Nr11,G(Nr11,1)*1.1
3465 FOR V=Nr11+1 TO Nr11+Mhr!Draw out the min 'M' neight
      above the inversion
3470 DRAW V,G(V,1)*1.1
3475 NEXT V
3480 LINE TYPE 2
3485 MOVE Nr11,G(Nr11,2)
3490 FOR V=Nr11+1 TO Nr11+Mhr! DRAW THE LIFTING
      CONDENSATION LEVEL
3495 DRAW V,G(V,2)
3500 NEXT V
3505 LINE TYPE 1!

3510 Profile:! COMPUTES AND PLOTS PREDICTED PROFILES
3515 SCALE -1.5,15,-1400,1200 ! Draw vertical lines in
      lower window

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3520 LINE TYPE 3
3525   FOR D=1.5 TO 13.5 STEP 3
3530   MOVE D,-1200
3535   DRAW D,0
3540   NEXT D
3545   LINE TYPE 1      !Get set for upper window
3550   CLIP 0,15,-1200,1200
3555   AXES 1,100,15,0,3,2,7
3560   GRAPHICS
3565   Sbd=0 ! FLAG FOR SURFACE BASED DUCT WARNING TO PRINT
        OUT
3570   CSIZE 2.7,.6
3575   FOR Cv=1 TO 5      ! label left side
3580   MOVE -.5,Cv*200
3585   LABEL USING "4D";Cv*200
3590   NEXT Cv
3595   Zg(1)=0
3600   Zg(4)=1200 !

3605   FOR Pr=0 TO 4
3610   Pm=Pr*150
3615   Hrg=Nrl1+6+12*Pr      ! Pull out hours for profiles
3620   FOR I=1 TO 4          ! Determine multiples to use for
        altitude
3625   Zg(2)=G(Hrg,1)
3630   Zg(3)=G(Hrg,1)*1.1 ! TO SET INVERSION THICKNESS =.1*
        HEIGHT
3635   ! COMPUTES Q AND THETA
3640   Pp1=G(Hrg,4)+(I>=3)*G(Hrg,6)+(I=4)*Dqdzu*(1200-Zg(3))
3645   Pp2=G(Hrg,5)+(I>=3)*G(Hrg,7)+(I=4)*Dtdzu*(1200-Zg(3))
3650   ! COMPUTES PRESSURE , VAPOR PRESSURE AND TEMP(K)
3655   P=Press-.120*Zg(I)
3660   E=P*Pp1/622
3665   T=Pp2-.0098*Zg(I)
3670   ! COMPUTES MODIFIED INDEX OF REFRACTION
3675   Pp(I)=77.6*P/T+373000*E/(T*T)+.157*Zg(I)
3680   NEXT I
3685   LORG 5 !Label bottom of 'M' profile
3690   SCALE 225,1050,-1400,1200
3695   MOVE Pm+375,-80
3700   LABEL USING "K";"350 400"
3705   MOVE Pp(1)+Pm,Zg(1)      ! Draw each profile
3710   FOR I=2 TO 4
3715   DRAW Pp(I)+Pm,Zg(I)
3720   NEXT I
3725   IF (Pp(3)<Pp(1)) OR (ABS(Pp(3)-Pp(1))<5) THEN GOSUB
        Sfc_duct
3730   LINE TYPE 3
3735   MOVE Pp(3)+Pm,Zg(3)
3740   DRAW Pp(3)+Pm,MAX(0,(Pp(3)-Pp(1))/(Pp(2)-Pp(1))*Zg(2))

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    )
3745  LINE TYPE 1
3750  MOVE 375+Pm,-1150          ! MOVE TO EACH SIX
    HOUR SPOT
3755  A=FNRelhum((G(Hrg,4)),(G(Hrg,5)))
3760  LABEL USING "3D.D";A
3765  NEXT Pr
3770  BEEP
3775  PAUSE
3780  EXIT GRAPHICS
3785  Hd$="N"
3790  INPUT "DO YOU WANT HARD COPY OUTPUT (N/Y)",Hd$
3795  IF Hd$[1,1]="N" THEN SUBEXIT
3800  PRINTER IS 0
3805  PRINT LIN(2)
3810  DUMP GRAPHICS
3815  IF NOT Sod THEN 3840
3820  PRINT LIN(2),"    The possibility of a surface
    based duct(SBD) is indicated and only"
3825  PRINT "due to the 'M' value greater at the surface
    than at the inversion"
3830  PRINT "height. Variation in the vertical structure
    must be emphasized"
3835  PRINT "when briefing this forecast in that a SBD may
    not exist."
3840  PRINT LIN(1),"    This is a SIMPLIFICATION of the real
    structure."
3845  PRINT LIN(1),"    This display is divided into UPPER
    and LOWER windows:"
3850  PRINT "LOWER WINDOW displays the top and middle
    of the elevated layer and its"
3855  PRINT "    forecast continued movement for a thirty
    hour period after beginning."
3860  PRINT "    At the bottom is the Relative Humidity at
    each six hour period."
3865  PRINT "    The lightly dotted line is the lifting
    condensation level."
3870  PRINT "    [With enough moisture near the inversion,
    this can be used"
3875  PRINT "    as a flag for possible cloud formation,
    or for high mixed-"
3880  PRINT "    layer humidity, near the surface, to
    forecast fog.]"
3885  PRINT "UPPER WINDOW picks out M-value structure (
    using only 4 points)"
3890  PRINT "    at each six hour period and will indicate a
    surface based duct"
3895  PRINT "    only if the elevated M-value is less than
    or within 5 of"
3900  PRINT "    the surface M-value. The sampled times are
    displayed at top."

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3905 PRINT PAGE
3910 SUBEXIT
3915 Sfc_duct: LORG 1
3920 BEEP
3925 LDIR 90
3930 MOVE Pp(3)+Pm-5,Zg(3)+20
3935 LABEL USING "K";"Surface Duct"
3940 Sbd=1
3945 LDIR 0
3950 LORG 5
3955 RETURN
3960 SUBEND!

3965 DEF FNRelhum(Q,T)
3970 T1=T-.0098*10
3975 C=23.84-2948/T1-5.03*LGT(T1)
3980 P=1012-.120*10
3985 Relhum=MIN(100,Q*100/(625*10^C/P))
3990 RETURN Relhum
3995 SUBEND!

4000 SUB We2(Zi,Zlcl,Dte,Dqw,Qs,Thr1,Qliq,Th1,Tsfc,Ust,Tst,
      Qst,Tstv,We2,Delr2,Tsky) ! NEED TO CALL PARCEL
      FIRST
4005 Dth=Dte-2500*Dqw
4010 Thr=Thr1+273.16
4015 Th=Th1+273.16
4020 Epsilon=.622 !RATIO OF WATER AND AIR
4025 Sigma=4.61E-11 ! STEFANS CONSTANT RELATING TEMP TO
      BLACK BODY RADIATION
4030 w1=Qliq*1250
4035 Emiss=MAX(0,1-EXP(-(Zi-Zlcl)*.138*w1/2))! EMISSIVITY
4040 Tc=Th-.0098*Zlcl ! TEMP AT BOTTOM OF CLOUD
4045 Tb=Thr-.0098*Zi ! TEMP AT TOP OF CLOUD
4050 Tbar=(Tb+Th)/2
4055 Dqsdt=.622*Qs*(2500/(.287*Tbar*Tbar))! Thr IS THETA
      AT THE CLOUD TOP
4060 Beta=(1+Th*(1+Epsilon)*Dqsdt)/(1+2500*Dqsdt)! L&L/Cp<-
      --2500 Cp=1
4065 D2=Beta*Dte-Tbar*Dqw ! IF NEGATIVE, THEN CLOUD
      TOP INSTABILITY
4070 Dthl=Dth-(Thr-Th)
4075 D1=Dthl*(1+Epsilon*Qs)+Epsilon*Tbar*Dqw ! QV=QS IN A
      CLOUD
4080 See=MIN(1,MAX(0,Zlcl/Zi)) ! TRAP SEE BETWEEN 0 AND 1
4085 DEF FNHvi(A)=MAX(0,A) ! HEAVISIDE FUNCTION
4090 Rb=Emiss*Sigma*(Tb^4-Tsky^4)! SHOULD BE POSITIVE
      UNDER MOST
4095 Rc=Emiss*Sigma*(Tsfc^4-Tc^4)! NORMAL CONDITIONS

```



```

4100 IF See=1 THEN Rb=Rc=0
4105 Wth=-Ust*Tst
4110 Wq=-Ust*Qst/1000 ! USING GRAMS PER GRAM
4115 Wthv=-Ust*Tstv
4120 Wthe=Wth+2500*Wq
4125 M1=(2-See)*See*FNHvi(Wthv)+(1-See)*(1-See)*FNHvi(Beta*
      Wthe-Th*Wq)
4130 N1=(2-See)*See*FNHvi(-Wthv)+(1-See)*(1-See)*FNHvi(-
      Beta*Wthe+Th*Wq)
4135 M2=See*See*(FNHvi(Rb)-Rc)+(1-See)*(1-See)*Beta*Rc+(1-
      See*See)*Beta*FNHvi(Rb)
4140 N2=See*See*FNHvi(-Rb)+(1-See*See)*Beta*FNHvi(-Rb)
4145 M3=(1-See*See)*FNHvi(-D2)
4150 N3=See*See*D1+(1-See*See)*FNHvi(D2)
4155 We2=(.2*(M1+M2)-(N1+N2))/(N3-.2*M3) !A=.2 RATIO OF
      ENTRAINMENT ENERGY
4160 IF We2>0 THEN GOTO 4135 ! TO TOTAL TKE
4165 IF (D2<0) AND (See<1) THEN We2=.005*(1-See*See)!CLOUD
      TOP INSTABILITY
4170 IF (D2<0) AND (See=1) AND (Wthv>0) THEN We2=
      .001!ENCROACHMENT
4175 IF (D2<0) AND (See=1) AND (Wthv<0) THEN We2=.0005
      !STABLE ENCROACHMENT
4180 IF We2<0 THEN We2=.0001
4185 Delr2=Rb-Rc ! DONE HERE CALCULATED FROM THE WATER
      CONTENT, TEMP OF SKY, CLOUD EMISSIVITY (THICKNESS
      OF CLOUD) TOP MINUS BOTTOM
4190 SUBEND!

```

```

4195 SUB Parcel0(The,Q10,Z,Rh,Th,Qv,Q1,Zs)
4200 Gam=.0098
4205 Gamdew=.00804
4210 Lcp=2.430
4215 Qq=Qt=Q10
4220 Zz=0
4225 GOSUB Td_find
4230 Td10=Td
4235 Zz=Z
4240 Thr=The-Lcp*Qt
4245 GOTO 4345
4250 Pheth:Th=Thez-Lcp*10
4255 Cycle:Tdo=Th-Gam*Z
4260 T=Tx=Tdo
4265 Zz=0
4270 GOSUB Qvcal
4275 Qv=Qvp
4280 GOSUB Dqdtcal
4285 Dthe=(Thez-(Th+273.16)*(1+Lcp*Qv/(T+273.16))+273.16)/
      (1+Lcp*Qv/(T+273.16)+(Th+273.16)/(T+273.16)*Lcp*Dqdt)
4290 IF ABS(Dthe)<.0001 THEN RETURN

```



```

4295 Th=Th+Dtne
4300 GOTO Cycle
4305 Dqdtcal:Tx=Tdo+.001
4310 GOSUB Qvcal
4315 Dqdt=(Qvb-Qv)/.001
4320 RETURN
4325 Qvcal: Qvb=5.3542*EXP(-5399.286*(1/(Tx+273.16)-3.5905E-
3))
4330 Sig=EXP(-1.1384E-4*Zz)
4335 Qvb=Qvb/Sig
4340 RETURN
4345 Zs=(Thr-Td10)/Gamdew
4350 IF Zs<0 THEN Zs=0
4355 IF Z>=Zs THEN GOTO 4400
4360 Th=Thr
4365 Tx=Th-Gam*Z
4370 Zz=Z
4375 GOSUB Qvcal
4380 Rn=Qt/Qvb*100
4385 Qq=Qv=Qt
4390 GOSUB Td_find
4395 GOTO 4420
4400 Thez=The
4405 GOSUB Theth
4410 Rh=100
4415 Td=Th-Gam*Z
4420 Ql=Qt-Qv
4425 SUBEXIT
4430 Td_find: Sig=EXP(-1.1384E-4*Zz)
4435 Qx=Qq*Sig
4440 Td=5399.286/(21.064-LOG(Qx))-273.16
4445 RETURN
4450 SUBEND!

```

```

4455 SUB Shrtwv(Theta,Qlbn,Zc,Zb,Qt,Dtemp)! ADDED BY
CHRIS FAIRALL 9FEB81
4460 IF (Zc>Zb) OR (Theta=PI/2) THEN Dtemp=0
4465 IF (Zc>=Zb) OR (Theta=PI/2) THEN SUBEXIT
4470 Qlbn=MAX(.00005,Qlbn)
4475 Qq=Qlbn/2
4480 DIM And(4),Dr(4)
4485 Cldthk=Zb-Zc
4490 Delz=Cldthk
4495 Dr(1.0)=2.5
4500 Dr(2)=5
4505 Dr(3)=10
4510 Dr(4)=20
4515 Sh=(Qt-Qq/Cldthk*Delz/2)*1.19 !WATER VAPOR
4520 Qq=Qq*1.19 !LIQUID WATER
4525 Rm=(4774.648*Qq)^.333

```



```

4530 FOR I=1.0 TO 4 ! XND IS THE XLOUD DROPLET SPECT
4535 Xnd(I)=.829963*EXP(-LOG(Dr(I)/Rm)*LOG(Dr(I)/Rm)*
      4.4164)*1E8
4540 NEXT I
4545 CALL Kannrad(Cldthk,Sh,Xnd(*),Theta,0,Fheat,Ftop,
      Fbotdir,Fbotdif)
4550 ! Fbotdir DOWNWARD DIRECT RAD AT CLOUD BOTTOM
4555 ! Fbotdif DOWNWARD DIFFUSE RAD AT CLOUD BOTTOM
4560 ! Ftop DOWNWARD DIRECT RAD AT CLOUDTOP
4565 ! Theta ZENITH ANGLE
4570 Dtemp=Delz*Fheat/Zb/60
4575 SUBEND
4580 SUB Int779(Nxy,X,Xarray(*),Yarray(*),Y,Slope,Ix)
4585 OPTION BASE 1
4590 Ix=MIN(MAX(1,Ix),Nxy-1)
4595 IF Xarray(Ix)<X THEN 4615
4600 IF Ix<=1 THEN 5020
4605 Ix=Ix-1
4610 GOTO 4595
4615 IF X<=Xarray(Ix+1) THEN 4635
4620 IF Ix+1>=Nxy THEN 5020
4625 Ix=Ix+1
4630 GOTO 4595
4635 Slope=(Yarray(Ix+1)-Yarray(Ix))/(Xarray(Ix+1)-Xarray(
      Ix))
4640 Y=Slope*(X-Xarray(Ix))+Yarray(Ix)
4645 GOTO 4655
4650 Ix=-999
4655 SUBEND
4660 ! SUB A52 - INITIALIZE XKV ARRAY
4665 SUB A52(Xkv(*),U)
4670 ! DISP "A52"
4675 ! U IS PATH IN G/CM^2
4680 OPTION BASE 1
4685 MAT Xkv=ZER
4690 Xkv(6)=.05/U^.39!.022
4695 Xkv(7)=.09/U^.39!.094
4700 Xkv(8)=.26/U^.39!.169
4705 Xkv(9)=.28/U^.26!.145
4710 Xkv(10)=.36/U^.26!.211
4715 Xkv(11)=.66/U^.53!.591
4720 Xkv(12)=.97/U^.53!.943
4725 Xkv(13)=1.06/U^.53!.943
4730 Xkv(14)=.39/U^.68!.76
4735 Xkv(15)=.31/U^.68!.685
4740 SUBEND
4745 ! SUB A20 - COMPUTE NEEDED ELEMENTS FOR AUGMENTE
      MATRIX A
4750 SUB A20(A(*),F,Al,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*),
      Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
4755 OPTION BASE 1

```





```

4760 ! DISP "A20"
4765 CALL A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
      Xkv(*),Iw,Tau(*))
4770 Fo=Fi(Iw)
4775 Fq=G*G
4780 G=G/(1+G)
4785 T=(1-Om*Fq)*T
4790 Om=(1-Fq)*Om/(1-Om*Fq)
4795 D1=1-Om
4800 D2=1-Om*G
4805 Xk=(3*D1*D2)^.5
4810 P=(3*D1/D2)^.5
4815 D3=1-Xk*Xk*Xmu*Xmu
4820 A1=3*Om*(Fo/PI)*Xmu*Xmu*(1+G*D1)/(4*D3)
4825 Be=3*Om*(Fo/PI)*Xmu*(1+3*G*D1*Xmu*Xmu)/(4*D3)
4830 A(1,1)=1+2*P/3
4835 A(1,2)=1-2*P/3
4840 A(1,3)=A1+2*Be/3
4845 A(2,1)=(1-Ag-2*(1+Ag)*P/3)*EXP(-Xk*T)
4850 A(2,2)=(1-Ag+2*(1+Ag)*P/3)*EXP(Xk*T)
4855 A(2,3)=(1-Ag)*A1-2*(1+Ag)*Be/3+Ag*Xmu*(Fo/PI)*EXP(-
      T/Xmu)
4860 .SUBEND
4865 ! SUB A30 - COMPUTE NET FLUXES - FTOP AND ARRAY FL
4870 SUB A30(F1,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),T,
      A1,Be,P,Iw,Xmu)
4875 OPTION BASE 1
4880 ! DISP "A30"
4885 T0=0
4890 I0=X(1)*EXP(-Xk*T0)+X(2)*EXP(Xk*T0)-A1*EXP(-T0/Xmu)
4895 I1=P*(X(1)*EXP(-Xk*T0)-X(2)*EXP(Xk*T0))-Be*EXP(-T0/
      Xmu)
4900 Fd=Fi(Iw)*Xmu !DOWNWARD COMP AT CLOUD TOP IW BAND,
      PERPIND TO HORIZONTAL
4905 Ftop=Ftop-PI*(I0-2/3*I1)+Fd !NET (D-U) AT CLOUD TOP,
      TOTAL
4910 Ftopd=Ftopd+Fd !TOTAL DOWNWARD COMP
4915 I0=X(1)*EXP(-Xk*T)+X(2)*EXP(Xk*T)-A1*EXP(-T/Xmu)
4920 I1=P*(X(1)*EXP(-Xk*T)-X(2)*EXP(Xk*T))-Be*EXP(-T/Xmu)
4925 F1=F1+4/3*PI*I1 !NET AT LEVEL
4930 F1=F1+Fd*EXP(-T/Xmu) !TOTAL NET (DIF+DIRECT) LEVEL I
4935 Fbotdif=Fbotdif+PI*(I0+2/3*I1)
4940 Fbotdir=Fbotdir+Fd*EXP(-T/Xmu)
4945 SUBEND
4950 ! SUB A28 - AVERAGE SA,AF ARRAYS AND STORE IN OM,G;
      COMPUTE T
4955 SUB A28(G,T,Om,Dr(*),Xnd(*),Qext(*),D,Sa(*),Af(*),Sh,
      Xkv(*),Iw,Tau(*))
4960 ! DISP "A28"
4965 OPTION BASE 1
4970 Om=G=Ts=0

```



```

4975   FOR J=1 TO 4
4980   Tau(J)=Qext(Iw,J)*PI*(Dr(J)*1E-6)^2*Xnd(J)*D
4985   Ts=Ts+Tau(J)
4990   NEXT J
4995   T=Ts
5000   FOR J=1 TO 4
5005   Om=Om+Sa(Iw,J)*(Tau(J)/Ts)
5010   G=G+Af(Iw,J)*Tau(J)/Ts
5015   NEXT J
5020   Vp=Sh*D*1E-4
5025   Om=Om/(1+Kkv(Iw)*Vp/T)
5030   SUBEND
5035   ! SUB A100 - COMPUTE QEXT,SA,AF ARRAYS - ROUTINE FROM
      A. GOROCH
5040   SUB A100(Qext(*),Sa(*),Af(*),Dr(*))
5045   ! DISP "A100"
5050   OPTION BASE 1
5055   DIM X19(15),Xn9(15),Xk9(15)
5060   DATA 0.25,0.35,0.45,0.55,0.65,0.75,0.85,0.95,1.05,1.15
5065   DATA 1.25,1.35,1.45,1.55,1.65
5070   DATA 1.362,1.345,1.335,1.333,1.332,1.3,1.329,1.327,
      1.326,1.325
5075   DATA 1.323,1.321,1.320,1.318,1.316
5080   DATA 2.5,5,10,20
5085   RESTORE 5060
5090   MAT READ X19,Xn9,Dr
5095   MAT Xk9=ZER
5100   REM EVALUATE EXTINCTION USING DEIRMENDJIAN
      APPROXIMATION
5105   FOR Ix9=6 TO 15
5110   X10=X19(Ix9)
5115   Xn0=Xn9(Ix9)
5120   FOR I=1 TO 4
5125   R2=Dr(I)
5130   R0=4*PI*R2/X10*(Xn0-1)
5135   Qsca=Qext(Ix9,I)=2
5140   Sa(Ix9,I)=Qsca/Qext(Ix9,I)
5145   IF Sa(Ix9,I)=1 THEN Sa(Ix9,I)=.9999999999
5150   Af(Ix9,I)=1.8*(.5+EXP(-4*R0)/R0+(EXP(-4*R0)-1)/(4*R0)^
      2)
5155   NEXT I
5160   NEXT Ix9
5165   ! DISP ""
5170   SUBEND
5175   SUB Kannrad(Cldthk,Sh,Xnd(*),Pheta,Itest,Fheat,Iinc0,
      Fbotdir,Fbotdif)
5180   ! DISP "KAHNRAD"
5185   OPTION BASE 1
5190   DIM A(2,3),R(3),X(2)
5195   DIM Qext(15,4),Sa(15,4),Af(15,4)
5200   DIM Dr(4),Tau(4),Alam(15)

```



```

5205 DIM Fi(15),Xkv(15)
5210 ! I. INITIALIZATION
5215 DATA .0165,.1580,.2839,.2765,.2318,.1822,.1435,.1149,
        .0948,.0792
5220 DATA .0643,.0518,.0424,.0348,.0238
5225 DATA .2,.5355,.803,.909,.953,.960,.960,.920,.933,.940,
        .850,.780,.770,.830,.910
5230 RESTORE 5215
5235 MAT READ Fi,Alam
5240 U=MAX(.05,Sh*Cldthk*1E-4)
5245 Fbotdir=Fbotdif=Ftop=Ftopd=Ftopdir=0
5250 IF Itest=1 THEN Theta=PI/4
5255 Xmu=COS(Theta)
5260 IF Xmu=0 THEN 5285
5265 Secmu=1/Xmu
5270 FOR I=1 TO 15
5275 Fi(I)=Fi(I)*Alam(I)^Secmu
5280 NEXT I
5285 Ag=.1 ! SURFACE ALBEDO
5290 IF Xmu>.7 THEN Ag=.05
5295 Delz=Cldthk
5300 Fl=0
5305 D=Delz
5310 CALL A100(Qext(*),Sa(*),Af(*),Dr(*))
5315 CALL A52(Xkv(*),U)
5320 ! II. SOLUTION OF EQUATIONS
5325 FOR Iw=6 TO 15
5330 CALL A20(A(*),T,A1,Be,P,Xk,Fi(*),Qext(*),Dr(*),D,Sa(*),
        Af(*),Sh,Xkv(*),Xnd(*),Ag,Iw,Xmu,Tau(*))
5335 ! PERFORM GAUSS ELIMINATION ON MATRIX A
5340 FOR L=1 TO 2
5345 Il=L
5350 Dd=A(L,L)
5355 IF ABS(Dd)>.000001 THEN 5405
5360 Il=Il+1
5365 IF Il>2 THEN 5545
5370 FOR Iwi=1 TO 3
5375 R(Iwi)=A(L,Iwi)
5380 A(L,Iwi)=A(Il,Iwi)
5385 A(Il,Iwi)=R(Iwi)
5390 NEXT Iwi
5395 Dd=A(L,L)
5400 GOTO 5355
5405 FOR Ibi=1 TO 3
5410 A(L,Ibi)=A(L,Ibi)/Dd
5415 NEXT Ibi
5420 FOR J=L+1 TO 2
5425 Dd=A(J,L)
5430 FOR K=1 TO 3
5435 A(J,K)=A(J,K)-Dd*A(L,K)
5440 NEXT K

```



```

5445 NEXT J
5450 NEXT L
5455 FOR K=2 TO 2 STEP -1
5460 FOR J=K-1 TO 1 STEP -1
5465 A(J,3)=A(J,3)-A(J,K)*A(K,3)
5470 A(J,K)=0
5475 NEXT J
5480 NEXT K
5485 FOR I=1 TO 2
5490 K(I)=A(I,3)
5495 NEXT I
5500 CALL A30(F1,Fbotdir,Fbotdif,Ftop,Ftopd,X(*),Xk,Fi(*),
      T,A1,Be,P,Iw,Xmu.)
5505 NEXT Iw
5510 ! III. OUTPUT MODULE
5515 Fheat=(Ftop-F1)/D*35.014
5520 Iinc0=Ftopd
5525 Ftop=Iinc0=Iinc0/1.7136
5530 Fbotdir=Fbotdir/1.7136
5535 Fbotdif=Fbotdif/1.7136
5540 SUBEND
5545 PRINT "INDETERMINATE"
5550 SUBEND
5555 SUB Sky2(Zi,Nsnd,Pot_temp(*),Zsnd(*),Spec_num(*),Tsky,
      Ftop)
5560 DATA 0,.00001,.0000215,.0000464,.0001,.000215,.000464,
      .001,.00215,.00464,.01,.0215,.0464,.1,.215,.464,1,
      2.15,4.64,10,21.5,46.4,-999
5565 DATA 0,1.86,2.58,4.11,5.72,7.81,11.4,14.6,18.3,23.6,
      27.7,31.9,37.4,41.7,46.2,52.9,59,66.6,78.8,88.1,
      95.1,98.8,-999
5570 DATA .0098,1.225,10094,4.61E-11,0,1,0
5575 OPTION BASE 1
5580 DIM Tu(23),Temis(23),Emit(2),Thrsnd(30),Qtsnd(30)
5585 RESTORE 5560
5590 MAT Qtsnd=Spec_num
5595 MAT Thrsnd=Pot_temp
5600 MAT READ Tu,Temis
5605 READ Gad,Rho0,Zscale,Sig,U,Ii,S
5610 Nemis=22
5615 ! THRSND() IS TH RADIOSND
5620 ! ZSND() IS ALTI IN M,RADSN
5625 ! NEMIS IS # OF EMISSIVITY POINTS IN TEMISS
5630 ! TU(23),U DATA
5635 ! TEMIS(23),EMISSIVITY DATA
5640 ! ITOP IS INDEX FOR ZSND=ZI, IE WHAT LEVEL IN RADSN
      IS AT INVERSION
5645 ! NSND IS NUMBER IS POINTS IN RADIOSND
5650 ! ICLOUD IS INDEX OF UPPER LEVEL CLOUDS
5655 Icloud=Nsnd !ASSUME NO UPPER LEVEL CLOUDS
5660 Jsnd=Nsnd-1

```





```

5665     IF Nsnd<=0 THEN SUBEXIT
5670     FOR Itop=1 TO Nsnd
5675         IF Zsnd(Itop)>Zi THEN GOTO 5685
5680         NEXT Itop
5685         Itop=Itop-1
5690     DISP "SKY2"
5695     Tts=Thrsnd(Itop)-Gad*Zsnd(Itop)
5700     Emit(Ii)=0
5705     FOR I=Itop+1 TO Nsnd-1
5710         Ii=3-Ii
5715         IF I>Icloud THEN GOTO 5785
5720         U=U+Qtsnd(I)*(.00005*(Zsnd(I+1)-Zsnd(I-1))*Rho0*EXP(-
            Zsnd(I)/Zscale))
5725     CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5730     Tt=Thrsnd(I)-Gad*Zsnd(I)
5735     S=S-Emit(Ii)*Sig*((Tt+273.16)^4-(Tts+273.16)^4)/100
5740     Tts=Tt
5745     NEXT I
5750     Tt=Thrsnd(Nsnd)-Gad*Zsnd(Nsnd)
5755     U=U+Qtsnd(Nsnd)*.0001*(Zsnd(Nsnd)-Zsnd(Nsnd-1))*Rho0*
        EXP(-Zsnd(Nsnd)/Zscale)
5760     CALL Int779(Nemis,U,Tu(*),Temis(*),Emit(Ii),Es,Ie)
5765     S=S+Sig*(Tt+273.16)^4*Emit(Ii)/100
5770     Icloud=Nsnd
5775     Ftop=0
5780     GOTO 5795
5785     Tt=Thrsnd(Icloud)-Gad*Zsnd(Icloud)
5790     Ftop=Sig*(Tt+273.16)^4
5795     Tsky=((Ftop*(1-Emit(Ii))+S)/Sig)^.25
5800     DISP ""
5805     SUBEND
5810     SUB Zenith(Time,Julday,Lat,Theta)
5815     RAD
5820         Hr=Time/3600 MOD 24-12
5825         Latr=Lat*.017453
5830         H=Julday*.017214
5835         Decl=.006913-.399912*COS(H)+.070257*SIN(H)-.006758*
            COS(2*H)+.000907*SIN(2*H)-.002697*COS(3*H)+
            .000143*SIN(3*H)
5840         Theta=ACS(SIN(Latr)*SIN(Decl)+COS(Latr)*COS(Decl)*
            COS(Hr*PI/12))
5845         IF Theta>PI/2 THEN Theta=PI/2
5850         SUBEND

```



## APPENDIX E:

### MAJOR PROGRAM VARIABLES IN PREDICTION CODE:

Alpha\_t ... ratio of heat transfer to momentum transfer  
exchange coefficient for neutral conditions ( $\Psi=0$ )

Aws ... subsidence rate value at initial inversion  
height[m/s]

Cdn ... neutral drag coefficient

Ctn\_sqrt ... square root of the temperature structure  
function parameter

Ddqwdt ... rate of change of specific humidity within the  
layer [g/kg-s]

Ddtedt ... rate of change of equivalent potential  
temperature within the layer [K/s]

Delr ... radiation flux divergence at cloud top [km/s]

Deltim ... prediction time step [1800 sec]

Dhdt ... rate of change of the mixed layer height and is  
the sum of entrainment and subsidence effects [m/s]

Dqdzu ... lapse rate of specific humidity above the  
layer [g/kg-km]

Dqw ... jump in specific humidity at the inversion [g/kg]

Dqwdt ... rate of change of specific humidity jump [g/kg-s]

Dtdzu ... lapse rate of potential temperature above the  
layer [K/km]

Dte ... jump in equivalent potential temperature at the  
layer [K]



Dtedt ... rate of change of equivalent potential temperature  
 Dtedzu ... lapse rate of equivalent potential temperature  
           above the layer [k/km]  
 Dth ... jump in potential temperature at the layer [k]  
 Kkk ... Von Karman constant (.35)  
 Lcp ... liquid water content  
 Mixq ... initial value of mixed layer specific humidity  
 Mixtemp ... initial value of mixed layer potential  
           temperature  
 Nrll ... beginning in half hour period [e.g. 1200=24]  
 Nrad ... 100 times the ratio of buoyancy in clouds  
 Press ... surface pressure, default to 1012 mb unless  
           entered from IREPS [mb]  
 Psil ... stability correction to logarithmic surface layer  
           wind profile. Determined from surface stability.  
           (Businger et al, 1971)  
 Psi2 ... stability correction to logarithmic surface layer  
           temperature and humidity profiles. determined from  
           surface stability. (Businger et al, 1971)  
 Ql0 ... Qp ... computed well-mixed specific humidity which  
           is assigned to the 10 meter level [g/kg]  
 Qst ... surface layer specific humidity scaling parameter,  
            $-wq/Ust$ , [g/kg]  
 Qw ... total (liquid + vapor) specific humidity [g/kg]  
 S ... surface layer stability ( $S=Z/L$ ,  $L$ =Monin-Obukhov length)  
 Tl0 ... well-mixed potential temperature which is assigned



to the 10 meter level [K]

Te ... equivalent potential temperature

Th ... well-mixed potential temperature in degrees Kelvin

Tsfc ... surface temperature [K]

Tst ... surface layer temperature scaling parameter [K]

Tstv ... surface layer virtual potential temperature scaling  
parameter [K]

U10 ... well-mixed wind speed which is assigned to the 10  
meter level [m/s]

Ust ... surface layer momentum scaling parameter [m/s]

Vdte ... advection above the layer

We ... entrainment rate [m/s]

Ws ... subsidence rate [m/s]

Wq ... surface flux of specific humidity [g/g]

Wst ... mixed layer convective scaling velocity [m/s]

Wto ... surface flux of temperature [K-m/s]

Wtv ... surface flux of vertical potential temperature  
(buoyancy flux) [K-m/s]

Zi ... height of the layer [m]

Zlcl ... lifting condensation level [m]

Zo ... surface roughness parameter for momentum [m]

Zot ... surface roughness parameter for temperature and  
humidity [m]

Zws ... initial height used for subsidence rate reference [m]





# VARIABLE CROSS REFERENCE

## MAIN PROGRAM

### COMMON VARIABLES:

Air	115	1070	1850				
Change	115	1070					
Coml(*)	120						
Delta	115	1070	1850				
Envnam\$ (*)	125	945	1005	1055			
Envsq(*)	120	930	965	995	1055	1060	
Evap\$	95	1060					
Height\$	95						
Height(*)	110	1065	1080	1090	1095	1455	1465
		1480	1620	1630	1865		
Htzero	115	1070					
Loc\$	95	440	490	530	1060	1335	1845
		1940	2630	2900			
Losnam\$ (*)	125						
Lossq(*)	120	930					
Munits(*)	110	1065	1865				
Name\$	95	1060					
Nmax	115	1070	1075	1080	1090	1095	1455
		1460	1465	1480	1620	1625	1630
		1865	1955				
Nunits(*)	110	1065					
Presur(*)	105	1065	1080	1865			
Przero	115	1070	1110	1850			
Recenv	115						
Relhm	115	1070	1850				
Relhum(*)	105	1065	1085	1865			
Sea	115	445	840	845	850	1070	1850
		2370					
Sysnam\$ (*)	125						
Syssq(*)	120	930					
Temper(*)	105	1065	1085	1090	1865		
Time\$	95	440	490	530	1060	1335	1845
		1945	2630	2900			
Type\$	95	1060					
Wind	115	575	580	1070	1850		
Wmo\$ (*)	100	1060					
Wmont\$	100	1060					

### VARIABLES:

Aa	265	285	290	295	300		
Alpha_t	190	2380	2430	2470	2490		
Aws	2130	2280	2285				
Cc	3000	3005	3010	3015			
Cdn	2350	2355	2375	2385	2430	2470	



Ctn_sqrt	2380	2385	2430	2470			
D	1780	1785	1790				
Date\$	220						
Ddqwdt	2235	2265					
Ddtedt	2235	2275					
Delr	2235						
Deltim	190	2245	2250	2260	2265	2275	2285
Dhdt	2235	2245					
Digit_top	1100	1460	1625	1860			
Dqdzu	1920	2115	2205	2220	2565		
Dqp	1915	2110	2120	2270			
Dqw	2120	2235	2265	2270	2310		
Dqwdt	2235	2250					
Dtdzu	1930	2115	2205	2565			
Dte	2110	2235	2275	2310			
Dtedt	2235	2260					
Dtedzu	2115	2205	2235				
Dth	1925	2110	2310				
Dummy	1035	1040	1045	1050			
Flag_data	360	1130	2525				
Flag_rev	310	365	1125				
Frame_date\$	155	1945	2565				
Frame_loc\$	155	1940	2565				
Ftop	1955						
G(*)	180	550	630	675	745	770	780
		1120	2025	2050	2060	2070	2215
		2240	2245	2255	2270	2305	2310
		2345	2565	2655	2660	2665	2670
		2805	2825	2855	2870	2940	2950
G1	2645	2650	2655	2660	2665	2670	2675
G2	2650	2670					
G3	2655	2670					
G4	2660	2670					
G5	2665	2670					
Hd\$	430	470	1835	2585	2590	2595	2600
		2625	2690	2895	2905	3020	3030
		3040					
Hight\$	1060						
I	940	945	950	960	990	995	1005
		1010	1015	1020	1075	1080	1085
		1090	1095	1100	1105	1860	1865
		1870	2040	2045	2050	2055	2060
		2080	2085	2810	2825	2855	2875
		2945	2950	2955			
Idayl	755	765	775				
Ier	910	915	920	925			
Inl1\$	535	540	545	550	565	595	610
		625					
Inl2\$	645	650	655	660	665	670	675
J	160	960	965	970	2020	2065	2070
		2075	2175	2185	2210	2215	2225



		2240	2245	2255	2270	2305	2310
		2325	2345	2850	2855	2865	
Julday	170	445	490	495	2230		
K	2795	2805	2825	2830	2845	2855	2870
		2885					
Kkk	190	2375	2380	2385	2430	2470	2490
		2495					
L	1235	1240	1250	1255	1270	1275	1280
		1285	1295	1300	1305	1310	1430
		1435	1440	1445	1460	1465	1470
		1625	1630	1635	2825	2830	2835
		2840					
L\$	165	2630	2635				
Lat	175	445	500	505	2230		
Lcp	2095	2105	2110	2115	2205	2300	2305
		2310					
Ll	1265	1275	1280	1290			
Mass\$	75	910	920				
Mhr	1960	1980	2175	2565	2645		
Mixq	1650	1660	1665	1685	1725	1730	1910
		1915					
Mixtemp	1490	1515	1525	1540	1575	1580	1900
		1925					
Mmm	1530	1650	1675	1780			
Mult	2490	2500	2505				
Nd	2055	2060	2065				
Nrl	2035	2040	2055	2060	2070	2080	
Nrll	565	620	630	675	745	755	770
		780	1980	1990	2020	2025	2035
		2145	2150	2155	2175	2210	2215
		2565	2645	2735	2740	2745	2755
		2765	2775	2785	2805	2825	2830
		2850	2870	2915	2925	2935	2940
		2945	2965	2980	2990	3000	
Nrec	1020	1030	1045				
Numhr	1980	2085					
O2	2220	2235					
P	2815	2855	2860				
Pot_temp(*)	165	1090	1455	1465	1480	1865	1955
Press	1110	1115	2565				
Psil	2405	2420	2430	2465	2470	2495	
Psi2	2410	2425	2430	2460	2470	2490	
Q\$	570	585	590	635	680	695	720
		725	730	735			
Ql0	2195	2235	2255				
Qdelta	2370	2385	2505				
Qp	1910	2105	2125	2195	2255	2370	
Qstar	2235	2505	2510				
Qw	2125	2250	2255	2305			
Rc\$	355	390	400	405	410	415	
Rec	995	1000	1005	1050	1055	1060	



Run\$	2170	2210	2215				
S	2385	2400	2420	2425	2430	2435	2440
		2450	2455	2470	2475	2480	
S1	2385	2435	2440	2475	2480		
So	2385	2390	2395	2430	2470		
Spec_hum(*)	165	1085	1620	1630	1645	1865	1955
Stick\$ (*)	155	190	1440				
T	2090	2095	2100	2295	2300		
T10	1900	2015	2190	2235			
Tday\$	220	225	235	240	445	1335	1975
		2565	2630				
Tdelta	2365	2385	2500				
Te	2105	2260	2305				
Th	2015	2090	2105	2110	2115	2190	2205
		2305	2310	2365	2385	2510	
Theta	2230	2235					
Timesec	2225	2230					
Top_inv_q	1675	1685	1690	1710	1735	1915	1920
Top_inv_temp	1530	1540	1545	1565	1585	1925	1930
Top_q	1700	1710	1740	1920			
Top_q_alt	1700	1710	1740	1920			
Top_temp	1555	1565	1590	1930			
Top_temp_alt	1555	1565	1590	1930			
Tsfc	850	2235	2365				
Tsky	1955	2235					
Tstar	2235	2500	2510				
Tstv	2235	2510					
Tt	2100	2105	2110	2115	2205	2290	2295
		2305	2310				
U10	2345	2350	2355	2385	2495		
Ustar	2235	2495					
Vdt	1995	2005					
Vdte	2005	2275					
Vss	2555	2565	2570				
Win	455	460	465	640	665	670	675
		685	690	705	710	715	760
		765	770	775	780	785	795
		800					
Win1	750	765	770				
Wind_begin1	575	600	605	610	625	630	
WindIn(*)	155	460	520	565	630	670	675
		710	745	765	770	775	780
		1250					
Wn	455	560	685	705	760	800	1235
Ws	205	1935	2130	2235	2280		
Wsl	205	445	825	830	1415	1935	
Wtv	2235						
X1	2450	2465					
X2	2455	2460					
X5	2060	2070					
Z	190	2375	2380	2385	2490	2495	





Zi	1475	1490	1505	1525	1565	1580	1585
		1645	1665	1710	1715	1730	1735
		1905	1920	1930	1955	1990	2025
		2090	2100	2130	2135	2180	2185
		2235	2245	2280	2290	2295	
Zil	2180	2290					
Zi3	1475	1715	1905				
Zlc1	2235	2240					
Zo	2375	2495					
Zot	190	2380	2490				
Zsnd(*)	165	1095	1955				
Zws	2135	2285					

#### USER DEFINED FUNCTIONS:

FNQvalue	1085	2370	
FNRelhum	2665	2940	2950

#### SUB PROGRAMS:

Frame	2565
M2	2235
Sky2	1955
Zenith	2230

#### JUMP TARGETS:

155	80							
190	185							
220 Start:	875							
255 Option:								
260 Menu:	290	295	300	305	360	410	415	1030
		1040	2335	2525	2570			
310 Start_out:	300							
315 Start_out_ag	405							
350 Revchange:	300	400	420					
425 List_curr:	415							
490 Jullat:	320	415						
515 Enter_winds:	325	415						
530	525	540						
610	590							
645 One_wind:	655	660	805					
695 Print_wind:	650	740	810					
745	730							
795 Fixwind:	735	800						
815 Subsidence:	330	415						
840 Sea_temp:	335	415						
860 Assig_error:	905							
880 No_data:	860	915	925					
900 Ireps_data:	245							
960 All_out:	935							
975 All_full:	955							
980 Disp_data:	315	415	1045					
1020 Pick_data:	1000							



1110		1080						
1140	Plt_struct:	340	415	1790				
1770		1785						
1885		1835						
1900	Run:	310	345					
2045		2050	2085					
2175	Looper:							
2340	Bulk:	2030	2320					
2420		2395	2445					
2450		2390	2485					
2490	Stars:	2415	2435	2475				
2520	Picture:	300	2550	2570	2580	2705	3040	3060
2585	Hard_output:	425	1830	2605	2615	2890		
2610	Gval:	2570						
2710	Mix_plot:	2570						
3065	Bye:	300						
3085		3075						
3095		3085						
3110	En:							

SUB PROGRAM M2

COMMON VARIABLES:

VARIABLES:

Cl	3130	3150		
Ddqwdt	3115	3205		
Ddtedt	3115	3200		
Delr	3115	3180	3200	3210
Dhdt	3115	3195		
Dqdzu	3115	3205		
Dqw	3115	3180	3205	3215
Dqwdt	3115	3215		
Dte	3115	3180	3200	3210
Dtedt	3115	3210		
Dtedzu	3115	3200		
Dtemp	3185	3200	3210	
Ql0	3115	3155	3160	3185
Ql	3160	3170	3185	
Qliq	3170	3180		
Qs	3165	3180		
Qst	3115	3145	3180	
Qv	3160	3165		
Rh	3160	3165		
Tl0	3115	3120	3155	3180
Te	3155	3160		
Thet	3125	3150	3200	3210
Theta	3115	3185		
Thr	3160	3180		
Tsfc	3115	3180		



Tsky	3115	3180					
Tst	3115	3135	3180				
Tstv	3115	3140	3180				
Tt	3120	3125	3130	3150			
Ust	3115	3135	3140	3145	3180		
We	3190	3195	3200	3205	3210	3215	
We2	3180	3190					
Wq	3145	3150	3205	3215			
Ws	3115	3195					
Wt	3135	3150					
Wte	3150	3200	3210				
Wtv	3115	3140					
Zi	3115	3120	3125	3160	3180	3185	3200
		3205	3210	3215			
Zlcl	3115	3160	3180	3185			

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

Parcel0	3160
Shrtwv	3185
We2	3180

JUMP TARGETS:

FNQvalue

COMMON VARIABLES:

VARIABLES:

Qvb	3230	3235
R	3225	3230
Tx	3225	3230

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM Frame::

COMMON VARIABLES:

VARIABLES:

A	3755	3760			
Bb	3370	3380	3385	3390	3400
Bbb	3375	3385	3400		
Cc	3360	3365	3370	3375	3395 3405



Cv	3410	3415	3420	3425	3575	3580	3585
		3590					
D	3525	3530	3535	3540			
Dqdzu	3245	3640					
Dtdzu	3245	3645					
E	3660	3675					
Frame(*)	3245						
Frame_date\$	3245	3310					
Frame_loc\$	3245	3310					
G(*)	3245	3430	3445	3460	3470	3485	3495
		3625	3630	3640	3645	3755	
Hd\$	3785	3790	3795				
Hrg	3615	3625	3630	3640	3645	3755	
I	3620	3640	3645	3655	3665	3675	3680
		3710	3715	3720			
Mhr	3245	3360	3440	3465	3490		
Nrll	3245	3270	3275	3280	3285	3305	3320
		3330	3350	3360	3415	3430	3440
		3460	3465	3485	3490	3615	
P	3655	3660	3675				
Pm	3610	3695	3705	3715	3735	3740	3750
		3930					
Pp(*)	3675	3705	3715	3725	3735	3740	3930
Ppl	3640	3660					
Pp2	3645	3665					
Pr	3605	3610	3615	3765			
Press	3245	3655					
Sbd	3565	3815	3940				
T	3665	3675					
Tday\$	3245	3300					
V	3440	3445	3450	3465	3470	3475	3490
		3495	3500				
Zg(*)	3255	3595	3600	3625	3630	3640	3645
		3655	3665	3675	3705	3715	3735
		3740	3930				

#### USER DEFINED FUNCTIONS:

FNRelhum 3755

#### SUB PROGRAMS:

#### JUMP TARGETS:

3510 Profile: 3815  
3840  
3915 Sfc\_duct: 3725

FNRelnum

#### COMMON VARIABLES:

#### VARIABLES:





C	3975	3985
P	3980	3985
Q	3965	3985
Relhum	3985	3990
T	3965	3970
Tl	3970	3975

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM We2

COMMON VARIABLES:

VARIABLES:

A	4085					
Beta	4060	4065	4125	4130	4135	4140
D1	4075	4150				
D2	4065	4145	4150	4165	4170	4175
Delr2	4000	4185				
Dqsdt	4055	4060				
Dqw	4000	4005	4065	4075		
Dte	4000	4005	4065			
Dth	4005	4070				
Dth1	4070	4075				
Emiss	4035	4090	4095			
Epsilon	4020	4060	4075			
M1	4125	4155				
M2	4135	4155				
M3	4145	4155				
N1	4130	4155				
N2	4140	4155				
N3	4150	4155				
Qliq	4000	4030				
Qs	4000	4055	4075			
Qst	4000	4110				
Rb	4090	4100	4135	4140	4185	
Rc	4095	4100	4135	4185		
See	4080	4100	4125	4130	4135	4140 4145
		4150	4165	4170	4175	
Sigma	4025	4090	4095			
Tb	4045	4050	4090			
Tbar	4050	4055	4065	4075		
Tc	4040	4095				
Th	4015	4040	4050	4060	4070	4125 4130
Th1	4000	4015				
Thr	4010	4045	4070			



Thrl	4000	4010					
Tsfc	4000	4095					
Tsky	4000	4090					
Tst	4000	4105					
Tstv	4000	4115					
Ust	4000	4105	4110	4115			
We2	4000	4155	4160	4165	4170	4175	4180
Wl	4030	4035					
Wq	4110	4120	4125	4130			
Wth	4105	4120					
Wthe	4120	4125	4130				
Wthv	4115	4125	4130	4170	4175		
Zi	4000	4035	4045	4080			
Zlcl	4000	4035	4040	4080			

USER DEFINED FUNCTIONS:

FNDhvi	4085	4125	4130	4135	4140	4145	4150
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SUB PROGRAMS:

JUMP TARGETS:

4185	4160
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SUB PROGRAM Parcel0

COMMON VARIABLES:

VARIABLES:

Dqdt	4285	4315					
Dthe	4285	4290	4295				
Gam	4200	4255	4365	4415			
Gamdew	4205	4345					
Lcp	4210	4240	4250	4235			
Q10	4195	4215					
Q1	4195	4420					
Qq	4215	4385	4435				
Qt	4215	4240	4380	4385	4420		
Qv	4195	4275	4285	4315	4385	4420	
Qvb	4275	4315	4325	4335	4380		
Qx	4435	4440					
Rh	4195	4380	4410				
Sig	4330	4335	4430	4435			
T	4260	4285					
Td	4230	4415	4440				
Td10	4230	4345					
Tdo	4255	4260	4305				
Th	4195	4250	4255	4285	4295	4360	4365
		4415					
The	4195	4240	4400				
Thez	4250	4285	4400				



Thr	4240	4345	4360				
Tx	4260	4305	4325	4365			
Z	4195	4235	4255	4355	4365	4370	4415
Zs	4195	4345	4350	4355			
Zz	4220	4235	4265	4330	4370	4430	

# USER DEFINED FUNCTIONS:

## SUB PROGRAMS:

## JUMP TARGETS:

4250 Theth:	4405		
4255 Cycle:	4300		
4305 Dqdtcal:	4280		
4325 Qvcal:	4270	4310	4375
4345	4245		
4400	4355		
4420	4395		
4430 Td_find:	4225	4390	

## SUB PROGRAM Shrtwv

## COMMON VARIABLES:

## VARIABLES:

Cldthk	4485	4490	4515	4545		
Delz	4490	4515	4570			
Dr(*)	4480	4495	4500	4505	4510	4535
Dtemp	4455	4460	4570			
Fbotdif	4545					
Fbotdir	4545					
Fheat	4545	4570				
Ftop	4545					
I	4530	4535	4540			
Qlbn	4455	4470	4475			
Qq	4475	4515	4520	4525		
Qt	4455	4515				
Rm	4525	4535				
Sh	4515	4545				
Theta	4455	4460	4465	4545		
Xnd(*)	4480	4535	4545			
Zb	4455	4460	4465	4485	4570	
Zc	4455	4460	4465	4485		

# USER DEFINED FUNCTIONS:

## SUB PROGRAMS:

Kahnrad	4545
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## JUMP TARGETS:



SUB PROGRAM Int779

COMMON VARIABLES:

VARIABLES:

Ix	4580	4590	4595	4600	4605	4615	4620
		4625	4635	4640	4650		
Nxy	4580	4590	4620				
Slope	4580	4635	4640				
X	4580	4595	4615	4640			
Xarray(*)	4580	4595	4615	4635	4640		
Y	4580	4640					
Yarray(*)	4580	4635	4640				

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

4595	4610	4630
4615	4595	
4635	4615	
4655	4645	
5020	4600	4620

SUB PROGRAM A52

COMMON VARIABLES:

VARIABLES:

U	4665	4690	4695	4700	4705	4710	4715
		4720	4725	4730	4735		
Xkv(*)	4665	4685	4690	4695	4700	4705	4710
		4715	4720	4725	4730	4735	

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A20

COMMON VARIABLES:

VARIABLES:

A(*)	4750	4830	4835	4840	4845	4850	4855
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Af(*)	4750	4765					
Ag	4750	4845	4850	4855			
Al	4750	4820	4840	4855			
Be	4750	4825	4840	4855			
D	4750	4765					
D1	4795	4805	4810	4820	4825		
D2	4800	4805	4810				
D3	4815	4820	4825				
Dr(*)	4750	4765					
Fi(*)	4750	4770					
Fo	4770	4820	4825	4855			
Fq	4775	4785	4790				
G	4765	4775	4780	4800	4820	4825	
Iw	4750	4765	4770				
Om	4765	4785	4790	4795	4800	4820	4825
P	4750	4810	4830	4835	4845	4850	
Qext(*)	4750	4765					
Sa(*)	4750	4765					
Sh	4750	4765					
T	4750	4765	4785	4845	4850	4855	
Tau(*)	4750	4765					
Xk	4750	4805	4815	4845	4850		
Xkv(*)	4750	4765					
Xmu	4750	4815	4820	4825	4855		
Xnd(*)	4750	4765					

# USER DEFINED FUNCTIONS:

## SUB PROGRAMS:

A28	4765
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## JUMP TARGETS:

## SUB PROGRAM A30

## COMMON VARIABLES:

## VARIABLES:

Al	4870	4890	4915			
Be	4870	4895	4920			
Fbotdif	4870	4935				
Fbotdir	4870	4940				
Fd	4900	4905	4910	4930	4940	
Fi(*)	4870	4900				
Fl	4870	4925	4930			
Ftop	4870	4905				
Ftopd	4870	4910				
IO	4890	4905	4915	4935		
Il	4895	4905	4920	4925	4935	
Iw	4870	4900				



P	4870	4895	4920				
T	4870	4915	4920	4930	4940		
TO	4885	4890	4895				
X(*)	4870	4890	4895	4915	4920		
Xk	4870	4890	4895	4915	4920		
Xmu	4870	4890	4895	4900	4915	4920	4930
		4940					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A28

COMMON VARIABLES:

VARIABLES:

Af(*)	4955	5010					
D	4955	4980	5020				
Dr(*)	4955	4980					
G	4955	4970	5010				
Iw	4955	4980	5005	5010	5025		
J	4975	4980	4985	4990	5000	5005	5010
		5015					
Om	4955	4970	5005	5025			
Qext(*)	4955	4980					
Sa(*)	4955	5005					
Sh	4955	5020					
T	4955	4995	5025				
Tau(*)	4955	4980	4985	5005	5010		
Ts	4970	4985	4995	5005	5010		
Vp	5020	5025					
Xkv(*)	4955	5025					
Xnd(*)	4955	4980					

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:

SUB PROGRAM A100

COMMON VARIABLES:

VARIABLES:

Af(*)	5040	5150
-------	------	------



Dr(*)	5040	5090	5125				
I	5120	5125	5135	5140	5145	5150	5155
Ix9	5105	5110	5115	5135	5140	5145	5150
		5160					
Qext(*)	5040	5135	5140				
Qsca	5135	5140					
R0	5130	5150					
R2	5125	5130					
Sa(*)	5040	5140	5145				
Xk9(*)	5055	5095					
Xl0	5110	5130					
Xl9(*)	5055	5090	5110				
Xn0	5115	5130					
Xn9(*)	5055	5090	5115				

# USER DEFINED FUNCTIONS:

## SUB PROGRAMS:

## JUMP TARGETS:

5060	5085
------	------

## SUB PROGRAM Kannrad

## COMMON VARIABLES:

## VARIABLES:

A(*)	5190	5330	5350	5375	5380	5385	5395
		5410	5425	5435	5465	5470	5490
Af(*)	5195	5310	5330				
Ag	5285	5290	5330				
Al	5330	5500					
Alam(*)	5200	5235	5275				
Be	5330	5500					
Cldthk	5175	5240	5295				
D	5305	5330	5515				
Dd	5350	5355	5395	5410	5425	5435	
Delz	5295	5305					
Dr(*)	5200	5310	5330				
Fbotdif	5175	5245	5500	5535			
Fbotdir	5175	5245	5500	5530			
Fheat	5175	5515					
Fi(*)	5205	5235	5275	5330	5500		
Fl	5300	5500	5515				
Ftop	5245	5500	5515	5525			
Ftopd	5245	5500	5520				
Ftopdir	5245						
I	5270	5275	5280	5485	5490	5495	
Il	5345	5360	5365	5380	5385		
Ibi	5405	5410	5415				



Iinc0	5175	5520	5525				
Itest	5175	5250					
Iw	5325	5330	5500	5505			
Iwi	5370	5375	5380	5385	5390		
J	5420	5425	5435	5445	5460	5465	5470
		5475					
K	5430	5435	5440	5455	5460	5465	5470
		5480					
L	5340	5345	5350	5375	5380	5395	5410
		5420	5425	5435	5450		
P	5330	5500					
Qext(*)	5195	5310	5330				
R(*)	5190	5375	5385				
Sa(*)	5195	5310	5330				
Secmu	5265	5275					
Sh	5175	5240	5330				
T	5330	5500					
Tau(*)	5200	5330					
Theta	5175	5250	5255				
U	5240	5315					
X(*)	5190	5490	5500				
Xk	5330	5500					
Xkv(*)	5205	5315	5330				
Xmu	5255	5260	5265	5290	5330	5500	
Xnd(*)	5175	5330					

#### USER DEFINED FUNCTIONS:

##### SUB PROGRAMS:

A100	5310
A20	5330
A30	5500
A52	5315

##### JUMP TARGETS:

5215	5230
5285	5260
5355	5400
5405	5355
5545	5365

#### SUB PROGRAM Sky2

#### COMMON VARIABLES:

##### VARIABLES:

Emit(*)	5580	5700	5725	5735	5760	5765	5795
Es	5725	5760					
Ftop	5555	5775	5790	5795			
Gad	5605	5695	5730	5750	5785		





I	5705	5715	5720	5730	5745		
Icloud	5655	5715	5770	5785			
Ie	5725	5760					
Ii	5605	5700	5710	5725	5735	5760	5765
		5795					
Itop	5670	5675	5680	5685	5695	5705	
Nemis	5610	5725	5760				
Nsnd	5555	5655	5660	5665	5670	5705	5750
		5755	5770				
Pot_temp(*)	5555	5595					
Qtsnd(*)	5580	5590	5720	5755			
Rho0	5605	5720	5755				
S	5605	5735	5765	5795			
Sig	5605	5735	5765	5790	5795		
Spec_hum(*)	5555	5590					
Temis(*)	5580	5600	5725	5760			
Thrsnd(*)	5580	5595	5695	5730	5750	5785	
Tsky	5555	5795					
Tt	5730	5735	5740	5750	5765	5785	5790
Tts	5695	5735	5740				
Tu(*)	5580	5600	5725	5760			
U	5605	5720	5725	5755	5760		
Zi	5555	5675					
Zscale	5605	5720	5755				
Zsnd(*)	5555	5675	5695	5720	5730	5750	5755
		5785					

#### USER DEFINED FUNCTIONS:

##### SUB PROGRAMS:

Int779	5725	5760
--------	------	------

##### JUMP TARGETS:

5560	5585
5685	5675
5785	5715
5795	5780

#### SUB PROGRAM Zenith

##### COMMON VARIABLES:

##### VARIABLES:

Decl	5835	5840
H	5830	5835
Hr	5820	5840
Julday	5810	5830
Lat	5810	5825
Latr	5825	5840
Theta	5810	5840 5845



Time 5810 5320

USER DEFINED FUNCTIONS:

SUB PROGRAMS:

JUMP TARGETS:



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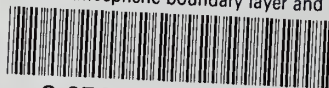
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